AUGUST 1953

Journal

VOL. 45 • NO. 8

AMERICAN WATER WORKS ASSOCIATION

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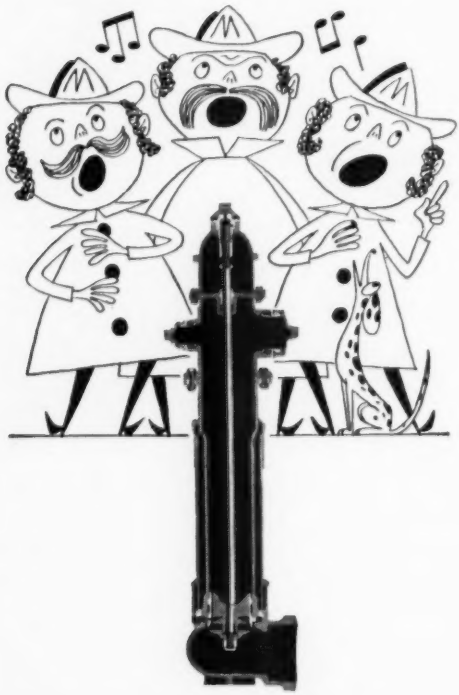

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150th anniversary

Journal

AMERICAN WATER WORKS ASSOCIATION

August 1953

Vol. 45 • No. 8

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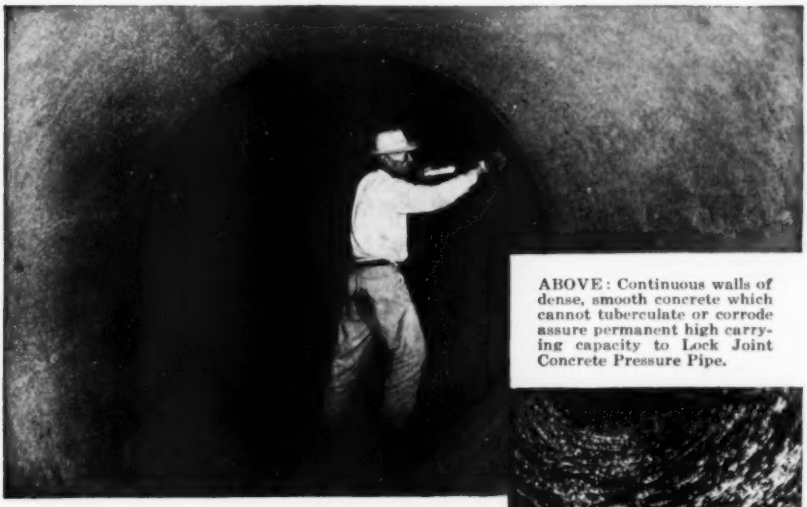

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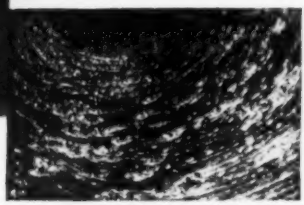

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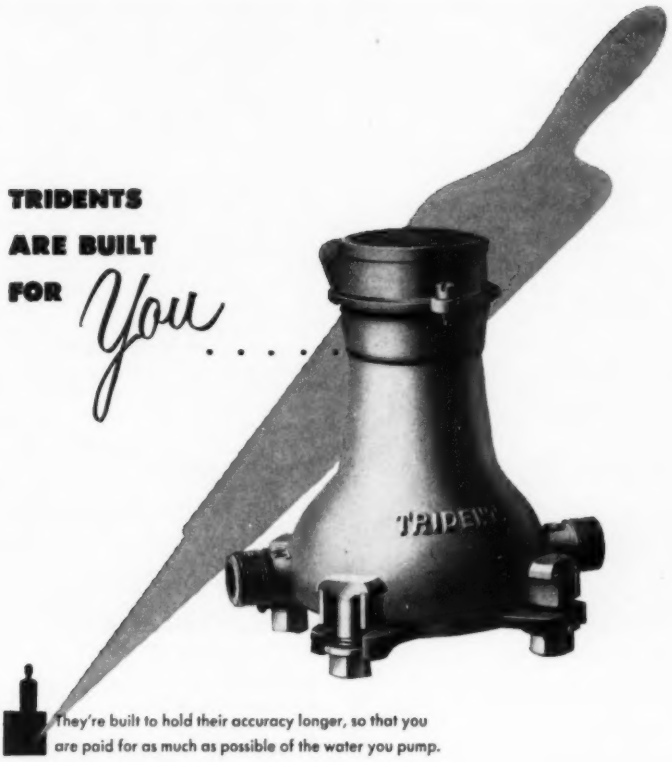

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Coming Meetings

AWWA SECTIONS

Sept. 3–4—West Virginia Section at Hotel Morgan, Morgantown. Secretary, Harry K. Gidley, Director, Div. of San. Eng., State Dept. of Health, Charleston.

Sept. 1–5—Minnesota Section at Royal Alexandria Hotel, Winnipeg. Secretary, Leonard N. Thompson, Gen. Mgr., Water Dept., St. Paul, Minn.

Sept. 3–4—Michigan Section at Hotel Delta, Escanaba. Secretary, T. L. Vander Velde, Chief, Sec. of Water Supply, State Dept. of Health, Lansing.

Sept. 9–11—New York Section at Lake Placid Club, Lake Placid. Secretary, Kimball Blanchard, Rm. 1922, 50 W. 50th St., New York 20, N.Y.

Sept. 10–11—Ohio Section at Hotel Cleveland, Cleveland. Secretary, M. E. Druley, Dist. Mgr., Dayton Power & Light Co., Wilmington.

Sept. 21–22—Maritime Branch, Canadian Section, at Fort Cumberland Hotel, Amherst, N.S. Secretary, J. D. Kline, Chief Engr., Public Service Com., Box 574, Halifax, N.S.

Sept. 21–23—Kentucky-Tennessee Section at Hotel Owensboro, Owensboro. Secretary, J. Wiley Finney, Jr., Asst. Director, State Dept. of Public Health, 420 6th Ave., N., Nashville 3, Tenn.

Sept. 22–23—Rocky Mountain Section at LaFonda Hotel, Sante Fe. Secretary, George J. Turre, San. Engr., Board of Water Comrs., Box 600, Denver, Colo.

Sept. 22–24—Wisconsin Section at Hotel Pfister, Milwaukee. Secretary, Leon A. Smith, Supt., Water & Sewerage, City Hall, Madison 3.

Sept. 27–29—Missouri Section at Elms Hotel, Excelsior Springs. Secretary, Warren A. Kramer, Div. of Health, State Office Bldg., Jefferson City, Mo.

Oct. 4–6—Alabama-Mississippi Section at Heidelberg Hotel, Jackson, Miss. Secretary, Charles W. White, Asst. San. Engr., State Dept. of Public Health, 537 Dexter Ave., Montgomery 4, Ala.

Oct. 11–13—Florida Section at McAllister Hotel, Miami. Secretary, William W. Aultman, Asst. Director, Dept. of Water & Sewers, Box 315, Coconut Grove Sta., Miami 33.

Oct. 14–16—Iowa Section at Russell Lamson Hotel, Waterloo. Secretary, H. V. Pedersen, Supt. of Water Works, Municipal Bldg., Marshalltown.

Oct. 18–21—Southwest Section at Rice Hotel, Houston. Secretary, Leslie A. Jackson, Mgr.-Engr., Municipal Water Works, Robinson Memorial Auditorium, Little Rock, Ark.

Oct. 22–24—New Jersey Section at Madison Hotel, Atlantic City. Secretary, C. B. Tygert, Wallace & Tiernan Co., Inc., Box 178, Newark 1.

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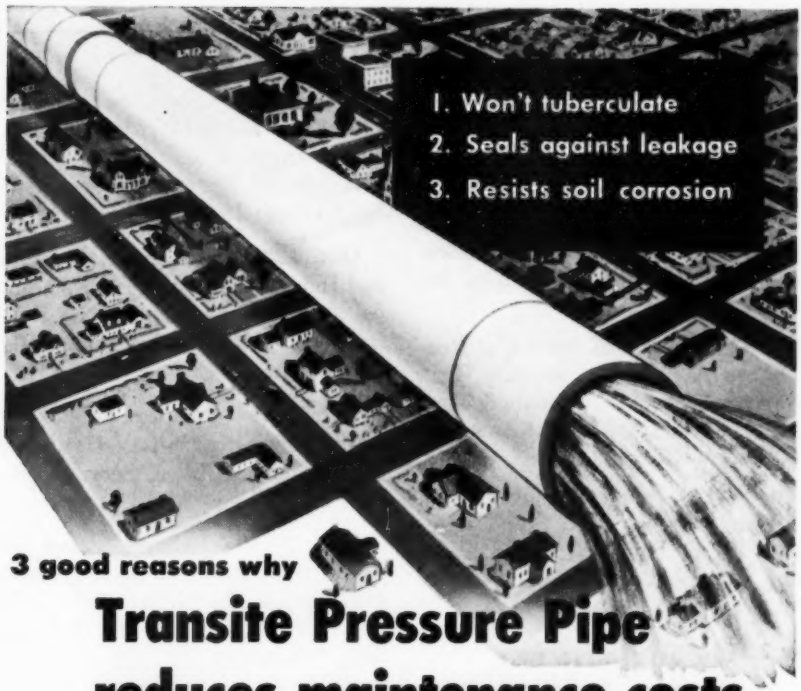

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Coming Meetings

(Continued from page 8)

Oct. 27–30—California Section at Palace Hotel, San Francisco. Secretary, John C. Luthin, 113 Laurent St., Santa Cruz.

Oct. 28–30—Chesapeake Section at Hotel DuPont, Wilmington, Del. Secretary, Carl J. Lauter, 6955—33rd St., Washington 15, D.C.

Nov. 4–6—Virginia Section at Roanoke Hotel, Roanoke. Secretary, J. P. Kavanagh, Dist. Mgr., Wallace & Tiernan Co., Inc., 915 Colonial-American Bank Bldg., Roanoke 11.

Nov. 9–11—North Carolina Section at Hotel Sheraton, High Point. Secretary, E. C. Hubbard, Exec. Secy., State Stream Sanitation Com., Box 2091, Raleigh.

1954 Section Meetings

Jan. 19—New York, in New York City
Mar. 17–19—Illinois, in Chicago
Apr. 7–9—Kansas, in Emporia
Apr. 12–14—Canadian, in Toronto, Ont.
Apr. 22–23—Nebraska, in Lincoln
Apr. 22–23—New York, in Watertown
Apr. 22–24—Arizona, in Tucson
Apr. 24–25—Montana, in Bozeman
May 23–28—AWWA, in Seattle
Sept. 15–17—Michigan, in Muskegon
Sept. 22–24—Ohio, in Dayton
Sept. 28–30—Wisconsin, in Green Bay
Oct. 17–20—Southwest, in El Paso, Tex.
Oct. 26–29—California, in Long Beach
Oct. 27–29—Chesapeake, in Baltimore.
Nov. 4–6—New Jersey, in Atlantic City

OTHER ORGANIZATIONS

Sept. 28–30—New England Water Works Assn., Poland Spring House, Poland Spring, Me. Details from Joseph C. Knox, Secy., 73 Tremont St., Boston 8, Mass.

Oct. 8–9—National Conference on Industrial Hydraulics, Sheraton Hotel, Chicago. Details from Otmar E. Teichman, Conference Director, Illinois Inst. of Technology, 35 W. 33rd St., Chicago 16, Ill.

Oct. 13–16—Federation of Sewage and Industrial Wastes Assns., Municipal Auditorium, Miami, Fla. Details from W. H. Wisely, 325 Illinois Bldg., Champaign, Ill.

Oct. 26–29—American Public Works Assn., New Orleans, La. Details from D. F. Herrick, Exec. Secy., 1313 E. 60th St., Chicago 37, Ill.

Oct. 27–30—National Water Well Assn. at Hotel Benjamin Franklin, Philadelphia, Pa. Details from Robert R. Storm, Exec. Secy., 811 W. Springfield, Champaign, Ill.

Nov. 8–11—National Inst. of Governmental Purchasing at Netherlands Plaza, Cincinnati, Ohio. Details from Albert H. Hall, Exec. Director, 730 Jackson Pl., N.W., Washington 6, D.C.

1954 Meetings

May 4–6—American Public Power Assn., in Chicago
June 13–18—American Society for Testing Materials, in Chicago
Sept. 13–15—New England Water Works Assn., in Dixville Notch, N.H.
Oct. 11–14—Federation of Sewage & Industrial Wastes Assn., in Cincinnati.
Oct. 11–15 (tentative)—American Public Health Assn., in Buffalo
Oct. 17–20—American Society of Civil Engineers, in New York City
Oct. 19–22—Pennsylvania Water Works Assn., in Atlantic City, N.J.
Nov. 28–Dec. 3—American Society of Mechanical Engineers, in New York.

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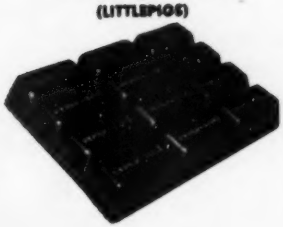

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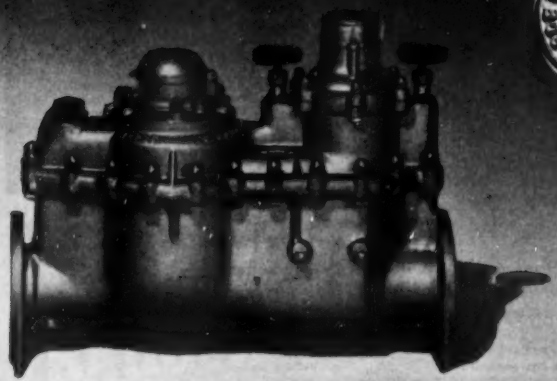

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"Century" Asbestos-Cement Pipe is made from two practically indestructible materials, asbestos fiber and portland cement. It cannot rust and is highly resistant to soil corrosion. That contributes to long life.

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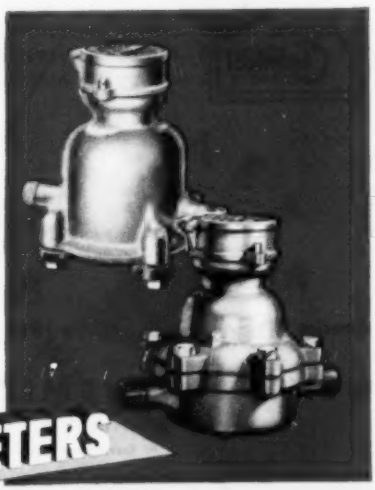

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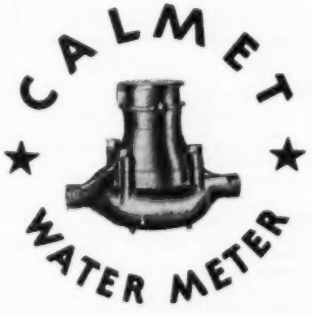

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Bethlehem Tar-Enameled Steel Pipe is widely used for water and sewage service because of its resilience, resistance to shock and corrosion, and leakproof joints. But the most important reason for its popularity is its great strength, which is evident in the chart below.

The chart shows the theoretical working and bursting pressures for various pipe diameters and thicknesses. The pressures shown are based upon the use of steel conforming to ASTM Specification A-283, Grade B, having a minimum ultimate tensile strength of 50,000 psi. When exceptionally severe working pressures are encountered, the use of higher strength steel is recommended for greater economy. The nearest Bethlehem office will be pleased to supply complete information.

THEORETICAL INTERNAL PRESSURES OF STEEL PIPE

	1/4 in.			5/16 in.			3/8 in.			7/16 in.			1/2 in.		
DIAM	WT LB/FT	MAX WRK PRESS PSI	MIN BURST PRESS PSI	WT LB/FT	MAX WRK PRESS PSI	MIN BURST PRESS PSI	WT LB/FT	MAX WORK PRESS PSI	MIN BURST PRESS PSI	WT LB/FT	MAX WORK PRESS PSI	MIN BURST PRESS PSI	WT LB/FT	MAX WORK PRESS PSI	MIN BURST PRESS PSI
22	63	365	1135	78	465	1420	93	550	1700	109	640	1985	124	730	2270
24	69	335	1040	86	420	1300	102	505	1560	119	585	1820	136	665	2080
30	86	270	835	108	340	1040	129	405	1250	150	475	1455	170	535	1670
36	106	225	695	130	280	870	155	340	1040	181	395	1210	206	445	1390
42	119	195	595	148	240	745	177	285	890	206	335	1040	234	380	1190
48	137	170	520	171	210	650	203	250	780	236	290	910	268	330	1040
54				192	190	580	230	225	695	267	260	810	303	295	925
60				214	170	525	255	200	625	296	235	730	336	265	835
72							309	170	520	359	195	605	408	220	695
84							357	145	450	412	170	520	470	190	595
96	The recommended minimum wall thickness is approximately the pipe diameter divided by 165. Pipe having this diameter-thickness ratio, when backfilled and properly tamped, will withstand any depth of cover. For buried pipe, the recommended minimum thicknesses are shown immediately above heavy black line.									470	145	455	539	165	520
108													611	150	465
120													669	135	415

$$P = \frac{t \times Ts}{r}$$

P = internal pressure, psi
t = thickness, in.
Ts = allowable unit stress = 60% x 27,000 (yield point) = 16,000 psi
r = radius of pipe, in.

BETHLEHEM STEEL COMPANY
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BETHLEHEM STEEL

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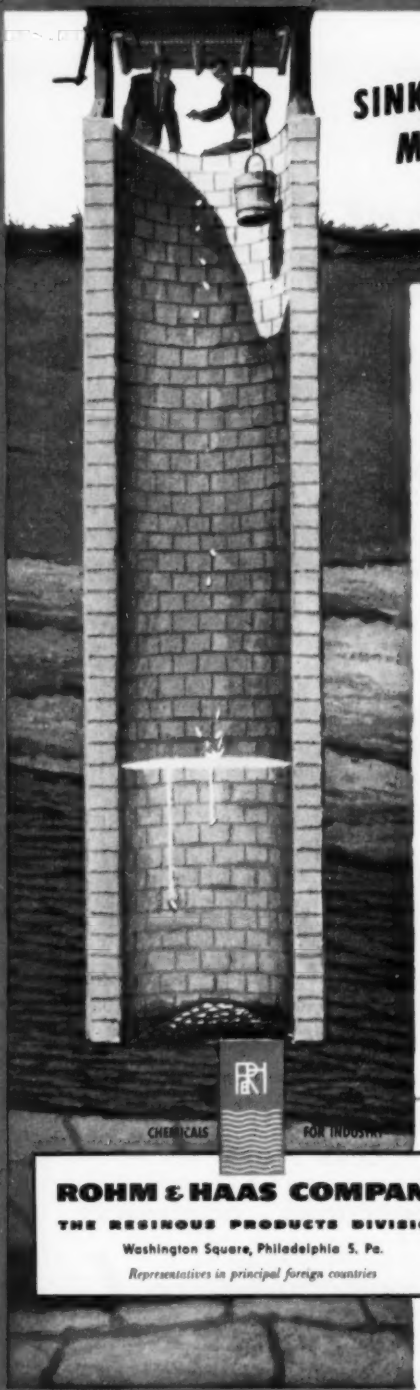

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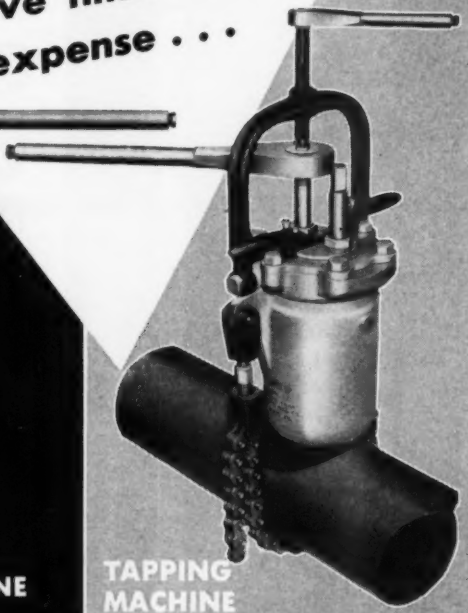

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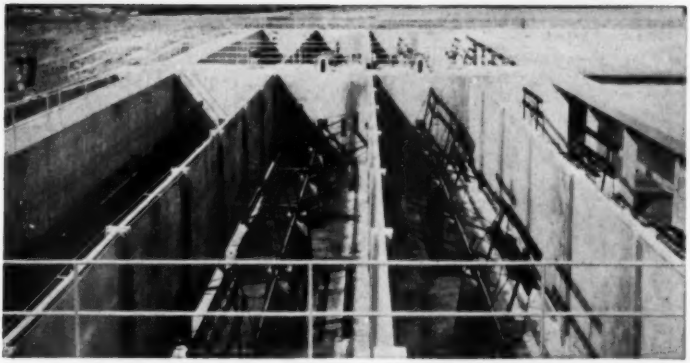
to meet your exact water treatment needs



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The "AMERICAN" Paddle Flocculation Unit has been particularly designed to efficiently carry out the slow mixing and flocculation functions required in the coagulation process. In addition, inherent design features have been utilized which allow for flexibility in operation, ease of installation, and simplified maintenance.

A choice of units is available which allows for adaptations to existing basins. Vertical paddle units in two basic styles can be utilized for smaller tanks, with horizontal multiple assemblies for the larger tanks.

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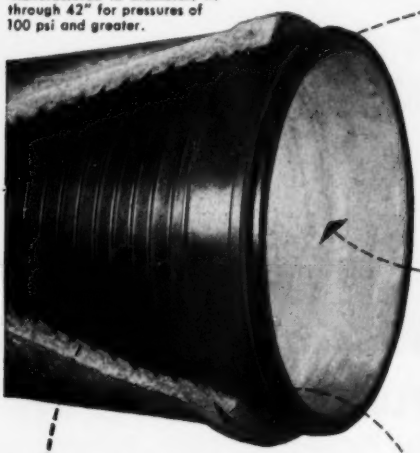
Manufactured in diameters 14" through 42" for pressures of 100 psi and greater.



1 Steel cylinder provides a positive water seal or membrane as well as part of the required total steel area*. (Thickness of the cylinder varies according to pipe diameters and general design requirements). Each cylinder is hydrostatically tested to a unit stress of at least 22,000 psi.

2 Centrifugally spun concrete lining is of proper mixture and dense compaction. Its thickness adds rigidity and strength through "arching" effect (nominal minimum lining thickness is ½" for 14" and 16" diameters and ¾" for larger diameters). Cylinder is lined prior to rod wrapping.

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*Total cross sectional steel area is based on 13,500 psi max. allowable unit stress at the design operating pressure.

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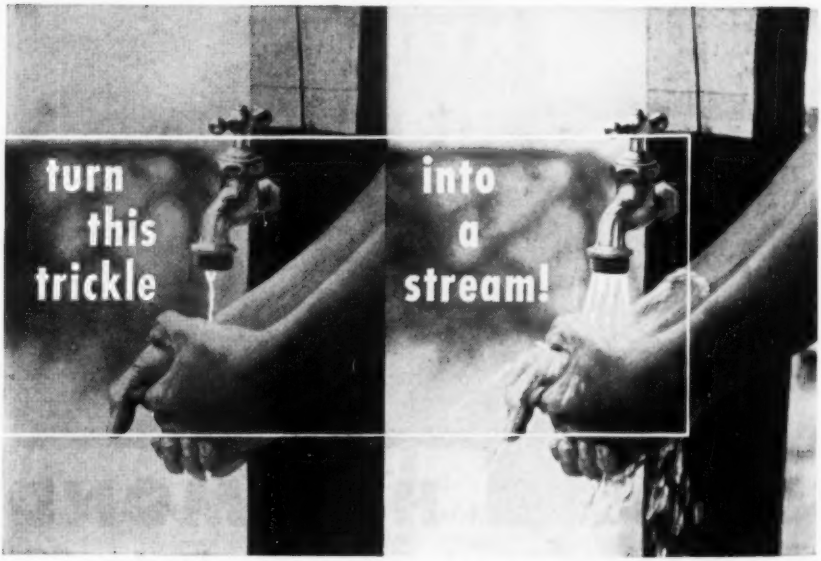

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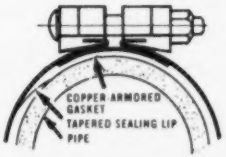

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- Easily installed under pressure in less than 10 minutes
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- Long (two inch) tapered gasket allows for variation in pipe size. Copper armor is molded into the gasket which gives strength, uniform sealing pressure, and ease of installation

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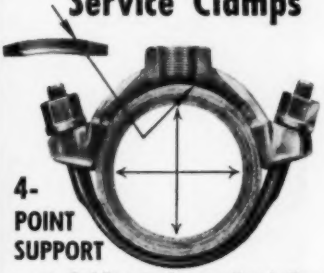

4-POINT SUPPORT

- Saddle extends more than half way around pipe to give 4-point support
- Taper seal neoprene gasket with hydromechanical sealing
- Made of the new waterworks material, ductile iron
- Delivered at a low cost to you
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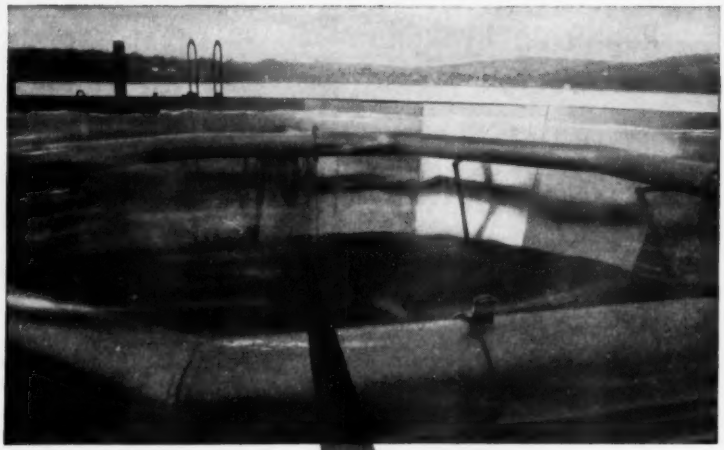
The BELCO Clarator produces multiple savings for a Utility

PROCESSES FOR REMOVAL OF WATER IMPURITIES



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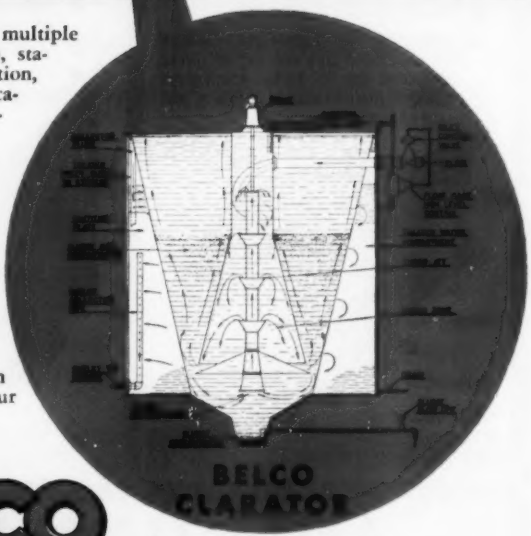

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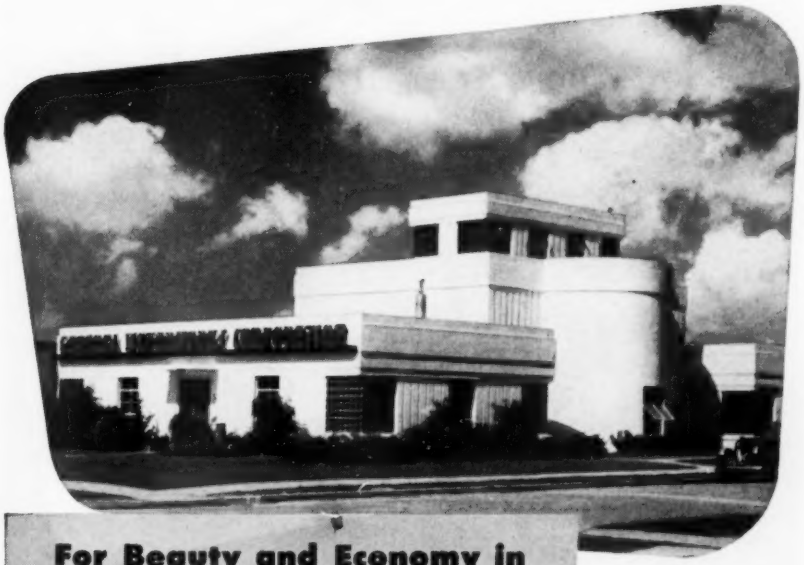

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Marion L. Crist & Associates, architects and engineers. Peterson & MacFayden, contractors. All of Little Rock, Ark.

Architectural concrete is ideal for modern waterworks buildings—and all other municipal structures. It can be used to create functional yet distinctive buildings like the General Waterworks plant in Pine Bluff, Ark. above. Such structures stand out as symbols of sanitation and good management and are a source of community pride.

Architectural concrete meets structural requirements for strength, durability and firesafety. And it can be molded economically into ornamentation of any style or period.

Architectural concrete is economical too. It is moderate in first cost, costs less to maintain and renders long years of service. These add up to ***low annual cost.***

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A national organization to improve and extend the uses of portland cement and concrete through scientific research and engineering field work

DELIVERS WATER CHEAPER

San Jose installs 12-mile Dresser-Coupled steel line . . . augments water supply from new reservoir.

Crossing the new Water Conservation District reservoir—replacing 8,000 ft. of flume, now submerged—this Dresser-Coupled steel line carries an increased water supply to San Jose, Los Gatos and Saratoga, California. Having installed over 200 miles of steel pipe since 1946, San Jose engineers are well acquainted with the many advantages of Dresser-Coupled construction.

The beam strength of lighter weight steel pipe, plus the resilience of both pipe and couplings, assures a permanently tight line unaffected by surface shock, ground shift or washouts. Rugged coatings make the line impervious to corrosion and incrustation. Glass-smooth pipe linings sustain high flow-coefficients.

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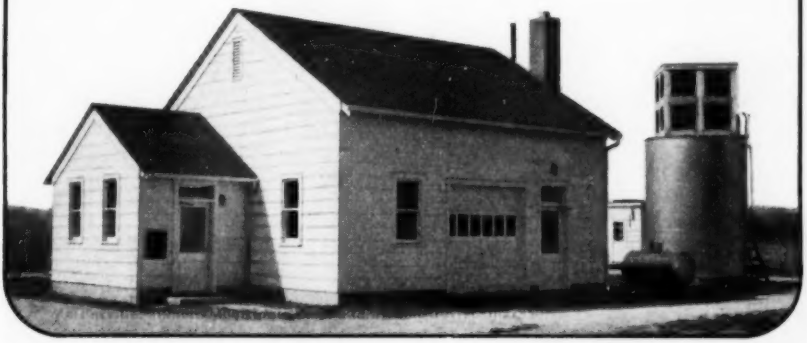
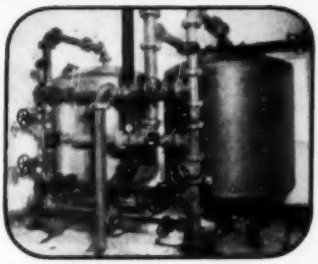


Martinsville, Illinois Municipal Water Plant



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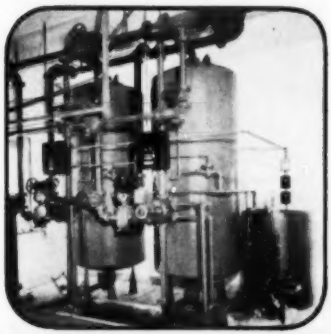

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Cost Indexes for Water Works Property

By Henry H. Fick

A paper presented on June 19, 1953, at the Pennsylvania Section Meeting, Hershey, Pa., by Henry H. Fick, Partner, Weber, Fick & Wilson, Public Utility Consultants, Harrisburg, Pa.

THE interest of engineers, accountants, bankers, architects, and contractors in the subject of indexes has always been greatest in periods of radical fluctuations of prices. Today more indexes are available and more people are using or are affected by them than ever before. Most newspapers publish the "Consumer Price Index" compiled and issued by the Bureau of Labor Statistics of the U.S. Dept. of Labor. Millions of workers became especially conscious of this index when it was made the basis for wage adjustments in contracts with employers. Like all measuring devices, indexes can be constructed with varying degrees of skill and refinement. Consequently, they can be used under varying conditions, depending upon the accuracy desired.

The past decade of increasing costs for nearly all construction and operating materials and labor has once again directed attention to indexes as a means of accurately and expeditiously measuring the direction and degree of price changes in the water works field. All individuals directly connected or associated with the problems of water works design, construction, management, operation, finance, and regulation can be served in some manner by indexes related to costs of water works property. An engineer engaged in the design of a water works project, or a contractor engaged in preparing bids or performing construction work, may employ indexes to determine the effects of increased costs. The accountant studying original costs of water utility property for continuing property records may likewise use indexes in estimating the historical cost of certain items for which original-cost records are missing. Management utilizes indexes in preparing operating budgets, reviewing insurance coverages, estimating capital replacement costs, and the

like. Finally, and of particular interest to water utilities under the jurisdiction of commissions that have adopted fair-value concepts for rate-making purposes, indexes are being used and continuously refined for purposes of preparing competent evidence of current and average costs of utility property.

The trending of the estimated or actual cost of water works property from one price base to another by the use of indexes would be a simple matter if all water systems were composed of the same types and relative amounts of physical units and if the fluctuations in the prices of such units were uniform regardless of location or local competitive conditions. Water works properties are as different as individuals, however, and the economy is not managed to such an extent that diversities due to competition are eliminated.

Although the gas, railroad, and electric utilities are served by recognized, useful published indexes for various geographical areas, the water works industry does not have similar data at its disposal. This is a natural result of the local character of water utilities, which do not tend to become integrated into large regional organizations, as do the gas, electric, and railroad utilities. The lack of a recognized published water works index should, of necessity, promote a better understanding of the correct composition and use of indexes, as each utility must apply them individually.

Water works properties are a heterogeneous mixture of many items that are not only unlike in kind but also unevenly distributed or of varying importance. Consequently, an index to measure the change of cost of the composite property must consider these variants as well as the applicability of basic trend or cost data used in the construction of component indexes. An index, whether related to a composite water works property or to a portion of it, must reflect the price changes of the specific kind of property. For example, if a distribution system is composed solely of cast-iron mains, an index for the material component must be based upon the price history of cast-iron pipe and no other. In spite of numerous decisions by appellate courts and regulatory agencies in the past, it is a fact that this axiom is frequently violated.

The total construction cost of a distribution system includes not only the costs of the material but also the associated costs of common and skilled labor, equipment rentals, contractors' overhead and profits, management expenses, and other tangible items. Therefore, if an index is being developed to reflect the changing construction costs of the distribution system, it is necessary to set up separate indexes for major variable cost components and to combine such component indexes in accordance with their relative importance. The latter procedure is known as "index weighting."

The concept of index weighting is not new. It is reported that, during a period of currency instability in Massachusetts, a law was enacted in 1778 to correct injustices to soldiers, who were paid for their services in scrip. At that early date, indexes were based upon the relative price changes of four basic commodities—corn, beef, wool, and sole leather. On offering their scrip for payment, soldiers received amounts of cash varying in accordance with the price index of these dissimilar commodities. In order to reflect the relative importance of each of these items

in the simple economy of that early date, they were weighted thus: corn, 5 bu; beef, 68¾ lb; wool, 10 lb; and sole leather, 16 lb. This example of index weighting in Revolutionary times might be considered the forebear of the present Consumer Price Index. Today, however, it appears that living standards have become so complicated that it is necessary to analyze and weight the price changes of approximately 300 items, ranging from frozen foods to television sets.

The applicability of available cost index data may be discussed under three general classifications of water works property: structures, equipment, and distribution system.

Structures

It is usual to classify water works structures in accordance with their function—reservoirs, filtration plants, pumping stations, office buildings, garages, storehouses, and the like. All of these structures have long lives and are usually designed with substantial margins to meet future demands. Because such construction is intermittent, individual water utilities generally do not have continuous cost data that would be useful in the computation of a series of building cost indexes. It is therefore necessary to use other sources.

The long-established construction and building cost indexes published by the *Engineering News-Record* have been widely used in trending this classification of water works property. The ENR "Construction Cost Index," which many have used for trending reservoirs, tank foundations, and other heavy construction, was first published in 1921. Annual indexes are available for 1903–52, as well as monthly indexes from January 1914 on. This index was designed to represent the price changes of a single unit of general construction having a base cost of $100 in 1913. Weighted amounts of construction materials (cement, steel, and lumber) and common labor are multiplied by national average unit costs in determining the index. The May 1953 ENR Construction Cost Index was 589.21 with 1913 taken as 100.0.

The ENR "Building Cost Index" was established in 1938. Annual indexes are available for 1910–52 and monthly indexes since January 1922. The composition of the index is identical with that of the ENR Construction Cost Index, except that 68.38 hours of skilled labor are priced rather than 200 hours of common labor. The May 1953 ENR Building Cost Index was 426.47 on the 1913 base.

It is believed that both indexes are extremely valuable to the water works field for certain purposes. They provide a sensitive barometer of the price changes of basic construction components that are least influenced by local conditions. The frequency of compilation and publication is of particular importance in a world of rapidly changing values.

The publishers of the ENR indexes regularly caution users that the indexes do not adjust for labor or job efficiency, material availability, competitive conditions, management, mechanization, or intangibles affecting construction costs.

A number of other building cost indexes, compiled and published by various engineering firms, large contracting organizations, and federal agencies, are reported in an excellent publication of the U.S. Dept. of Commerce, *Construction and Building Materials*. Information is supplied from 1915 to the

present date. Those desiring the benefits of more current reporting of certain indexes may receive the information by subscription.

As might be expected, the various building cost indexes may have different base periods, components, and regional emphasis. It is therefore necessary, before employing an index, to make certain that it is relevant to the situation under review. The uninformed use of published indexes may produce startling variations in results although each may be accurate in particular circumstances. For example, if the original cost of a building constructed in 1913 was $10,000, estimates based on 1951 average costs might range from $33,700 to $53,200, depending upon the index selected.

Space does not permit an examination of each of the indexes reported or in common usage. Instead, an analysis of four building indexes, compiled by different organizations, has been made. Three of these indexes have been used in rate proceedings before the Pennsylvania Public Utility Commission, and the fourth is a component of the Interstate Commerce Commission "Railroad Index." The indexes selected are: [1] the ENR Building Cost Index; [2] the E. H. Boeckh and Associates index for brick and concrete commercial and factory buildings in the Pittsburgh, Pa., area; [3] the Handy-Whitman index for brick buildings in the North Atlantic region; and [4] the ICC index for station and office buildings (Group III, including portions of Pennsylvania, Ohio, Illinois, Indiana, New Jersey, West Virginia, Delaware, and Maryland).

Briefly, the ENR Building Cost Index, as mentioned before, is composed of four material and labor items. The Boeckh index is said to be based upon material prices paid by contractors to material dealers, labor at current rates paid by contractors (corrected for labor efficiency and shortages in certain areas), construction overheads, taxes, and insurance. The Handy-Whitman index includes fourteen items of building construction, while the ICC index is based upon various items of information, including analyses of major construction contracts.

A study of each of these indexes from 1916 to 1951 shows that, in general, the changes reported from year to year are comparatively uniform. In certain years, however—for example, in 1918—there are substantial differences in the reported changes from the preceding year. One index (ENR) reports a decrease of 4.6 per cent in 1918, while the others show increases ranging from 10.4 per cent (Handy-Whitman) to 17.8 per cent (Boeckh). Other differences, particularly in earlier years, indicate that any use of the indexes for long-range purposes should be made only after careful study.

Although the period 1942–51 witnessed substantial price increases, a comparison of the yearly fluctuations of each of these indexes shows more substantial uniformity than in the past. The average maximum annual change between the highest and lowest reported change was only 5.06 per cent. The ICC index reported the highest average annual change, while the ENR index reported the lowest. Undoubtedly, the differential reflects such factors as labor efficiency, contractors' overhead, and intangibles, which are not included in the ENR index.

The relative uniformity of annual changes in these indexes implies that each can be used with a reasonable de-

gree of accuracy, but, if the period of review is prolonged, the cumulative differences tend to reach appreciable amounts. Assuming that a structure was built in 1942 at a cost of $10,000, the trended cost at 1951 average prices would range from $18,010 (ENR) to $19,760 (ICC), a difference of 9.7 per cent, with the other indexes producing figures of $18,680 (Boeckh) and $18,870 (Handy-Whitman). It is believed that any further extension of the review period may result in even greater differentials, although not necessarily involving the same indexes.

This comparison is intended not as an adverse criticism of these building cost indexes but merely as an illustration of differences that can arise by reason of the composition of the index, the area covered, or the type of building construction. Each of these indexes undoubtedly serves a useful purpose and, under certain circumstances, might be preferable to the others. A comparison of other published building cost indexes would undoubtedly produce similar conclusions.

Equipment

The category of water works equipment includes pumps, motors, interior piping and valves, controls, boilers, turbines, trucks, automobiles, office furniture, and similar items. Inasmuch as the associated costs of installation labor and minor appurtenances are usually relatively unimportant, it is the common practice to apply cost indexes to the equipment items without compositing. If the associated costs are unusually large, however—as would be true for special foundations for boilers, pumps, or turbines, for example—and if this expense is not included in the cost of the structure housing the equipment, a composite index may be developed by assigning appropriate weights to the equipment and heavy-construction indexes.

The development and application of equipment indexes are relatively simple for two reasons. First, the cost data upon which they are primarily based can be obtained from quotations by manufacturers on identical or similar items. Second, equipment items generally have a shorter life span than other water works property, and, therefore, more accurate historical pricing data are available. Nevertheless, when equipment indexes are being prepared for a considerable number of years, as necessitated, for instance, in an analysis of trended original cost, it is not unusual to find interruptions in a series of price quotations. These interruptions may result from changes in specifications, the complete discontinuance of a model, or a change in the basis of the price quotation. At each interruption for any of the foregoing reasons, the prices before and after the break would not be comparable, making it necessary to calculate relative prices in order to provide continuous, comparable indexes over the time period.

The foremost example of a break in a price series and a consequent adjustment for index purposes is provided by cast-iron pipe. Prior to 1950 cast-iron pipe prices were usually based upon net tons fob Delaware River foundries. Excellent price data are available on this base for a period of 100 years. Since 1950, however, quotations at Delaware River foundries have been discontinued by one major company, which now quotes prices fob Birmingham, Ala. *Engi-*

TABLE 1

Year	Building				Materials	
	*A**	*B*†	*C*‡	*D*§	6-in. and Larger Cast-Iron Pipe‖	1¼-in. Wrought-Iron Pipe#
1913	100.0	100.0		100.0	100.0	100.0
1914	91.9	96.4		100.0	89.4	100.9
1915	95.3	97.9	101.0	109.0	98.2	104.5
1916	130.9	131.6	115.0	141.0	135.3	140.0
1917	166.8	135.5	135.0	192.0	236.7	215.5
1918	159.1	159.6	154.0	212.0	259.5	237.3
1919	158.8	175.2	185.0	233.0	245.1	241.4
1920	207.2	239.8	216.0	262.3	316.6	252.7
1921	166.0	199.1	193.0	226.0	234.0	233.8
1922	154.8	176.7	181.0	211.0	220.1	233.7
1923	186.0	193.0	195.0	226.0	259.2	247.7
1924	185.8	201.9	194.0	232.8	254.4	254.5
1925	182.7	207.1	189.0	229.0	221.0	254.5
1926	185.0	210.3	185.0	229.0	215.0	254.5
1927	186.1	211.1	190.0	225.0	182.3	254.5
1928	188.0	210.9	188.0	219.3	158.8	254.5
1929	190.9	216.0	187.0	217.8	153.4	241.5
1930	185.4	217.5	182.0	207.3	165.9	235.9
1931	169.4	191.4	166.0	195.0	147.6	235.5
1932	140.9	161.7	142.0	175.3	130.1	228.2
1933	147.8	175.4	147.0	176.3	161.8	209.6
1934	166.7	166.5	152.0	196.0	188.6	206.4
1935	165.8	162.6	152.0	195.0	193.0	206.4
1936	172.2	194.7	158.0	198.5	195.6	210.2
1937	196.1	214.5	168.0	214.0	222.5	234.7
1938	196.8	223.5	168.0	212.5	217.9	229.5
1939	197.4	223.9	168.0	214.0	213.1	226.4
1940	202.8	224.2	177.0	218.3	223.4	226.4
1941	211.5	229.9	191.0	235.0	223.4	226.4
1942	222.4	239.8	209.0	249.3	223.4	226.4
1943	228.7	247.9	218.0	252.3	223.4	226.4
1944	234.7	261.8	224.0	256.5	223.4	226.4
1945	239.1	278.2	241.0	267.0	223.4	226.4
1946	262.3	298.7	288.0	305.3	279.1	249.5
1947	313.0	341.0	331.0	350.8	343.4	290.9
1948	344.5	394.9	363.0	402.3	416.4	339.1
1949	351.8	413.2	369.0	423.8	421.3	380.9
1950	375.2	421.4	390.0	439.0	397.9	389.5
1951	400.6	448.1	413.0	470.5	465.0	415.5
1952	415.6	467.1		479.2	472.7	421.5
Dec. 1952	425.3	477.4		485.0	487.8	440.0

* Based on *Engineering News-Record* Building Cost Index.
† Based on E. H. Boeckh and Assocs. Brick and Concrete Commercial and Factory Buildings Index, Pittsburgh, Pa., area.
‡ ICC Railroad Construction Index, Station and Office Buildings, Group III (not converted; 1910–14 = 100.0).
§ Based on Handy-Whitman Brick Buildings Index, North Atlantic Div.
‖ Based on *Iron Age* index, New York City.
Based on Handy-Whitman index, North Atlantic Div.

Cost Indexes

Materials				Common Labor§§	Construction‖‖	Gas Utility Costs**
Motors**	Contractors' Equipment††	Office Equipment††	Meters‡‡			
100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	94.0	94.7	100.0	93.2	88.6	99.1
100.0	97.1	97.3	100.0	95.8	92.6	103.7
100.0	107.1	108.9	112.5	101.0	129.6	125.9
132.0	140.0	118.3	100.0	147.9	181.2	172.2
146.0	194.6	142.7	162.5	200.0	189.2	212.0
176.0	204.8	166.1	162.5	245.3	198.4	227.8
197.5	245.1	220.4	162.5	304.7	251.3	249.1
198.0	190.0	168.4	162.5	284.2	201.8	209.3
166.0	132.5	139.5	162.5	232.6	174.4	200.9
136.0	154.4	146.1	162.5	272.6	214.1	215.3
136.0	170.2	145.3	162.5	292.1	215.4	220.4
136.0	167.3	147.1	162.5	283.2	206.7	213.4
134.2	158.7	136.8	162.5	288.4	208.0	212.0
129.0	152.2	130.9	162.5	291.6	206.2	205.6
131.2	153.6	131.9	162.5	292.6	206.8	200.0
134.2	144.4	124.2	162.5	287.9	207.0	201.9
134.8	136.7	119.2	162.5	295.3	202.8	200.0
134.0	123.2	108.3	162.5	263.2	181.3	192.6
134.0	114.1	101.1	162.5	224.7	157.0	174.5
139.8	114.0	103.8	162.5	240.0	170.2	166.7
155.2	120.6	108.6	162.5	280.0	198.1	193.5
150.0	126.5	114.2	132.9	277.9	196.4	200.9
150.0	131.7	119.2	132.9	296.8	206.4	203.7
150.0	138.4	122.2	147.7	339.5	234.7	223.1
150.0	131.6	119.0	147.7	356.8	235.8	225.9
147.8	130.8	123.5	147.7	359.5	235.5	229.6
147.0	132.4	127.2	147.7	367.9	242.0	235.2
147.0	146.0	134.6	167.4	391.0	257.8	244.4
154.0	160.0	144.2	177.3	423.2	276.3	254.2
154.0	160.8	145.3	177.3	448.9	289.9	257.4
145.8	161.3	148.4	177.3	462.6	298.7	259.3
148.2	162.7	149.9	177.3	478.9	307.7	268.5
173.8	197.1	174.6	186.8	543.7	346.0	309.3
210.0	238.6	214.0	192.0	627.9	413.2	364.8
218.8	255.7	230.4	242.1	710.5	460.7	413.9
232.0	255.7	220.9	265.9	763.2	477.0	432.9
251.2	263.8	230.9	284.3	805.3	509.1	447.2
297.0	281.4	248.2	310.2	852.6	542.0	481.5
296.5	282.2	247.2	310.2	914.7	568.9	495.4
295.0	283.0	247.3	310.2	956.3	587.5	500.0

** Based on Handy-Whitman index, North Atlantic Div.
†† Based on Marshall and Stevens index.
‡‡ Private sources.
§§ Based on *Engineering News-Record* Labor Index, 20-city average.
‖‖ Based on *Engineering News-Record* Construction Cost Index.

TABLE 2

Cost Indexes for Water Works Property Components

Year	Reservoirs	Buildings	Pumps and Motors	Distribution System	Services	Meters	Other Equipment
1913	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1914	88.6	96.4	100.0	90.5	97.6	99.3	94.4
1915	92.6	97.9	100.0	97.4	100.8	99.6	97.2
1916	129.6	131.6	100.0	125.1	125.0	111.2	108.1
1917	181.2	135.5	132.0	210.1	186.4	104.8	128.4
1918	189.2	159.6	146.0	241.7	221.3	166.2	166.8
1919	198.4	175.2	176.0	245.1	243.1	170.7	184.1
1920	251.3	239.8	197.5	313.0	275.0	176.7	231.9
1921	201.8	199.1	198.0	249.1	255.5	174.6	178.4
1922	174.4	176.7	166.0	223.9	233.2	169.5	136.3
1923	214.1	193.0	136.0	263.2	258.4	173.5	150.0
1924	215.4	201.9	136.0	265.7	270.7	175.4	156.9
1925	206.7	207.1	136.0	239.6	266.9	174.5	156.5
1926	208.0	210.3	134.2	237.0	269.1	175.0	147.0
1927	206.2	211.1	129.0	215.1	270.5	175.4	140.7
1928	206.8	210.9	131.2	199.0	270.9	175.5	142.1
1929	207.0	216.0	134.2	193.8	261.5	175.0	133.7
1930	202.8	217.5	134.8	204.8	261.5	175.7	127.2
1931	181.3	191.4	134.0	182.2	247.4	172.5	115.3
1932	157.0	161.7	134.0	158.5	226.7	168.7	107.1
1933	170.2	175.4	139.8	185.3	222.7	170.2	108.5
1934	198.1	166.5	155.2	216.0	238.0	174.2	114.3
1935	196.4	162.6	150.0	218.5	237.1	147.4	119.8
1936	206.4	194.7	150.0	226.0	247.4	149.3	125.0
1937	234.7	214.5	150.0	257.5	279.8	166.8	129.7
1938	235.8	223.5	150.0	259.7	284.2	168.6	124.8
1939	235.5	223.9	147.8	257.0	283.6	168.8	126.9
1940	242.0	224.2	147.0	266.8	287.2	169.7	129.7
1941	257.8	229.9	147.0	273.7	297.2	189.8	140.0
1942	276.3	239.8	154.0	283.3	311.0	201.9	151.6
1943	289.9	247.9	154.0	291.1	322.0	204.5	152.5
1944	298.7	261.8	145.8	295.2	327.9	205.9	154.4
1945	307.7	278.2	148.2	300.1	334.9	207.5	155.9
1946	346.0	298.7	173.8	358.5	376.0	222.5	185.1
1947	413.2	341.0	210.0	428.8	435.8	235.6	225.3
1948	460.7	394.9	218.8	504.7	498.8	288.9	242.2
1949	477.0	413.2	232.0	523.8	545.3	315.6	237.0
1950	509.1	421.4	251.2	520.1	568.3	336.4	246.3
1951	542.0	448.1	297.0	581.3	603.4	364.5	249.0
1952	568.9	467.1	296.5	605.3	633.6	401.7	248.8
Dec. 1952	587.5	477.4	295.0	627.9	662.0	405.8	249.3

neering News-Record is currently publishing fob prices in 21 major cities for 6–24-in. Class B or heavier cast-iron pipe. *Iron Age* publishes similar prices fob New York City only. Thus, in the construction of a continuous cast-iron pipe index from 1850 to 1953, it is necessary to adjust either series of price data by the relation between the two series at the point of interruption. The same principles would apply to the construction of indexes

for all other types of equipment with interrupted price series.

Price data for equipment indexes are comparatively abundant. Prices of commonly used equipment can be obtained from the files of the consulting engineer or utility. Equipment manufacturers are cooperating in the computation of indexes that are applicable to various classifications of their products. In addition, indexes are published by various consulting engineers and federal agencies. For example, the firm of Marshall and Stevens, Inc., Chicago, publishes quarterly indexes which cover the comparative equipment costs of 47 industries. Several of these indexes are believed to be applicable to the more general types of equipment found in water utilities, such as office and contractors' equipment, steam and electric power equipment, and so forth. Another source of prices or indexes is the "Wholesale Price Index" of the Bureau of Labor Statistics of the U.S. Dept. of Labor, particularly Group 10—Metals and Metal Products and Group 11—Machinery and Motive Power.

Considering the many types and varying degrees of importance of equipment items found in water systems, it is not believed that any one index is suitable for the trending of all equipment costs.

Distribution System

Transmission and distribution mains, services, meters, and fire hydrants are included in the distribution system category. The total cost of each of these elements includes the separate costs of materials and installation labor, the latter varying with the type of material installed. An index to be used in the trending of any of these elements must weight each of the material and labor components.

Under certain conditions, a utility may have continuing property records or other data which separate material and labor costs, the former including appropriate charges from stores clearing accounts and the latter containing charges from transportation and equipment clearing accounts. In such instances, the trending procedure is simplified by the application of appropriate indexes related to the separate price changes of the material and the labor component. It will be seen that, by this method, a composite index for materials and labor will accurately reflect the changes of labor productivity and other tangible or intangible components. If detailed and precise experience data are not available for material and labor weighting, estimates must be made.

TABLE 3

Weighted Components for Two Typical Plants

Component	Plant *A* per cent	Plant *B* per cent
Land	1	13
Reservoirs	5	17
Buildings	10	25
Pumps, motors, etc.	5	5
Mains	60	32
Services	10	2
Meters	7	4
Other equipment	2	2
Total	100	100

The sources for price changes in materials used in water works distribution systems are similar to those previously described for water works equipment. Data on changes in labor rates can be supplied by the utility,

local contractors, labor unions, or federal and state employment agencies. When all of the latter sources of labor rates are inadequate, it may be necessary to use published indexes, such as those of *Engineering News-Record* or the U.S. Dept. of Labor.

is assumed to be unchanged since 1913).

For the purpose of this presentation, sample indexes were prepared for two water utilities. Although not precisely applicable to specific water utilities, the indexes illustrate the effects of

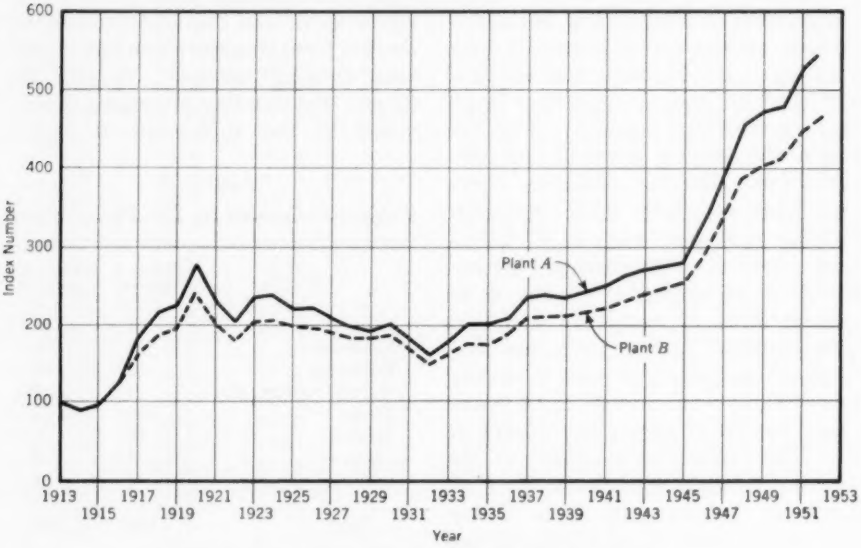

Fig. 1. Typical Water Utility Cost Indexes

The cost indexes for two water plants are shown for the period 1913–52, with 1913 taken as the base year. The weighted components of water plant property are given in Table 3.

Component Cost Indexes

The author has taken a number of cost indexes applicable to the various components of water works property and converted them to a 1913 base (Table 1). From these converted indexes, Table 2 has been prepared, to show cost indexes for the following water works property components: reservoirs, buildings, pumps and motors, distribution system, services, meters, and other equipment (land cost

historical price changes upon two systems with identical kinds but dissimilar amounts of property. Actually, the basic components of the two systems reflect the approximate dispersion of various classifications of property of two existing Pennsylvania utilities. For simplicity, however, it has been assumed that: [1] all structures are made of brick and concrete; [2] the transmission and distribution systems are composed of cast-iron mains; [3] services are constructed of

wrought-iron pipe; and [4] equipment includes motors, pumps, office, and contractors' items. The weighted components are shown in Table 1, and the indexes, based on 1913 = 100.0, are given graphically in Fig. 1.

The varied composition of the two properties naturally produces substantial differences in index numbers for given years. Plant A, having 60 per cent of its entire property in the form of distribution mains, has higher index numbers than Plant B, except for 1914. Plant B, which can be compared to a water works in a large city, has more land, reservoirs, and filtration and pumping plant structures than Plant A and therefore has lower index numbers. It may be of interest to note that the Handy-Whitman annual index figures for gas utilities in the North Atlantic Div., when converted to a 1913 base, fall between the two typical water works indexes in 33 of the 41 years and in all years since 1932.

The index numbers for the two plants vary considerably over a long period, but, if the indexes for the two plants during 1943–52 are converted to a 1943 base, they show relatively greater uniformity in reflecting the progressive price increases of the period. The average of the indexes for plants A and B in the 10-year period, when compared to indexes of other properties computed in a more detailed fashion, varied at most only 2.8 per cent in any one year, with an average annual variation (excluding the base year) of only 0.4 per cent.

It is believed that, with the exception of systems composed entirely of distribution facilities, water utilities will generally have cost indexes within the range of indexes of plants A and B. The latter, however, only suggest and do not specifically indicate the fluctuations in construction costs for a particular water works.

Erosion Control in Reservoir Areas

Task Group Report

A task group report presented on May 14, 1953, at the Annual Conference, Grand Rapids, Mich., by Burton S. Grant, Chairman, Task Group E3.A—Watershed Protection and Erosion Control; Chief Engr. of Water Works and Asst. Mgr., Los Angeles Dept. of Water and Power, Los Angeles. The other members of the task group were: E. J. Allen, Morrison B. Cunningham, Louis M. Euler, Dana E. Kepner, W. A. Kunigk, B. S. Morrow, Alfred J. Ryan, and Paul Weir.

THE problem of erosion of lands tributary to water supply reservoirs has, in recent years, become of increasing importance to the water works field. During the early development of the United States, water supplies and reservoir sites existed in abundance, and their conservation assumed less economic importance. With increases and shifts in population, however, people have made inroads on both these vital natural resources which can no longer be ignored. As Colman (*1*) has stated: "Man himself has entered the water-yielding lands and a number of his activities there have affected the water yield. Forests have been cut, burned, and cleared. Natural grasslands and brushlands have been grazed, burned, and plowed. Over vast areas native vegetation has been replaced with cultivated plants, and tillage has created a new kind of soil, periodically bare surfaced, stirred frequently to plow depth, and otherwise quite different from that present under undisturbed conditions."

The increased use of virgin lands for recreational purposes by a growing population has aggravated these conditions through road construction, clearing of land for camp sites, and increased incidence of forest fires.

In the face of these developments, which are, for the most part, natural and reasonable, it has become generally accepted that the conservation of water supply and reservoir sites must assume its place, along with other factors, in the general economic balance that constitutes the best possible ultimate use of the native land. With the acceptance of this point of view, the problem has become one of technological development, careful planning, and good management in order to make the most of available resources. These considerations constitute, particularly in the West, the most recent phase in the ever-increasing struggle for water.

Background Developments

The science of watershed ecology, which provides the technical tools for watershed management, has been developed to an advanced degree over the past 20–30 years by a number of agencies, particularly the Forest Service and the Soil Conservation Service of the U.S. Dept. of Agriculture. These two federal agencies, through full-scale experiments on forests and farms, have been the major contributors in establishing the relationship between plant growth, water yield, and soil erosion. The conclusion drawn

from their work, which is of the greatest importance to water works men, is that the problem of erosion control—and, for that matter, of water conservation itself—is a problem of controlling the runoff hydrograph. From the smallest rivulet out of a plowed field to the largest streams, the manner and character of the runoff is important, not only during the time it traverses the land, but also at the point it first enters the water system, which is usually an upstream storage basin.

An uncontrolled hydrograph from a barren, erodible watershed requires increased reservoir capacity both to conserve water that might otherwise go over the spillway and to offset loss in storage due to silt accumulation over the period of economic life of the reservoir. In a sense, the siltation problem is the more severe, as a water supply, once established, will not depreciate, hydrologically speaking, but a reservoir site can depreciate completely through siltation. In fact, it may be extremely shortsighted to consider only the economic life of a reservoir, because all too often it is an irreplaceable facility that must be regarded as permanent.

In addition to the technical developments in the field, legislation has been enacted to permit the active application of the technical work. The Soil Conservation and Domestic Allotment Act of 1935 established the Soil Conservation Service, which, in addition to its research work, is intended as an advisory agency for individuals or organizations desiring assistance in matters pertaining to watershed and soil management. The act also provides for the allotment of funds to local conservation districts engaged in erosion control programs.

The need for further legislation at the federal level has been recognized by the President's Water Resources Policy Commission. The report of this commission (*2*) discusses the watershed management problem in considerable detail and cites the need for adjustments in federal policies to keep pace with the growing problems of soil conservation and erosion control.

At the state level, each of the states and territories has adopted legislation providing for the establishment of conservation districts. Usually these comprise not more than one county and are administered by boards composed of local citizens. At present there are approximately 2,500 such districts, covering nearly 1.5 billion acres. The districts work closely with the Soil Conservation Service in planning and administering their programs.

In addition to these major legal implementations, there has been an increasing amount of municipal and other local legislative activity designed to promote erosion control. In Southern California, residential development of hillside areas and "view" lots has often completely disregarded proper terracing, drainage, or protection of the chaparral cover. Many of these areas are on watersheds adjacent to municipal reservoirs. In the winter of 1951–52, heavy rains resulted in mud flows that destroyed houses, plugged streets, and brought thousands of tons of sediment into reservoirs. The severity of the damage prompted the council of a large city to pass ordinances specifically controlling such residential construction in an effort to prevent recurrence of this type of damage.

Current Developments

Even a cursory review of the development of watershed management and erosion control cannot fail to reveal what is considered by the task group to be the most important fact in the

present state of the problem: most of the major developments and applications in the field have been carried out, not by the water works industry, but by agricultural, timber, grazing, and flood control interests. Benefits gained by water utilities have not been the result of efforts by those directly concerned with the public water supply. This situation is, perhaps, a consequence of the physical relationships involved. Obviously, the reservoir subject to sedimentation is at the opposite end of the chain of events that begins when a rain drop hits the ground high up in a watershed. Between these extreme points, the other interests mentioned above are doing what they can to reduce the ravaging effects of uncontrolled runoff, and the reservoir is thereby benefited even though the water works man may not have turned a hand. This seems to explain in part the apathy that water works men have shown toward the erosion and sedimentation problem. The rest of the explanation lies in the lack of knowledge of the serious effect of the sedimentation problem on water works management. The sediment, being out of sight, therefore tends to be out of mind as well. It must be remembered, however, that a reservoir silting at a rate of 1 per cent per year is not uncommon, and, although it would take 100 years to fill with silt, in 50 years its real usefulness is much more than half gone and in only 25 years it may no longer fit into the hydrologic framework for which it was designed.

In the face of these realities, it is encouraging to note that some water works men are not only recognizing the problem but attacking it with vigor. One such instance is the watershed management program of the Tacoma, Wash., Dept. of Public Utilities on the Green River watershed. The nature of this watershed has been adequately described by Kunigk (*3*) and need not be detailed here. It is sufficient to say that the area covered consists of approximately 230 sq miles of timbered, mountainous terrain, in which logging is the principal activity. The land is under diverse ownership, a portion being federal forest reserve. Since 1952 an intensive watershed control program has been putting into practice nearly all of the technical advances that have been made in watershed management. The program includes a sediment load study of the Green River, a study of logging operations and construction practice in the watershed, a soil-sampling program, and an investigation of forest influences. In order to control watershed activities, Tacoma is preparing a publication that will, in effect, provide general specifications for logging and construction practice in the area. Although these requirements are partially supported by state public health regulations, the success of the program is dependent primarily on the cooperation of private interests in the area. The fact that the program has already substantially reduced sediment flow into the city's principal storage unit is indicative of what can be done when all parties concerned are made aware of the soil erosion problem. Tacoma has worked closely with the Forest Service and the logging operators to achieve results that are, in the final analysis, beneficial to all.

In the Cedar River watershed of Seattle, Wash., terrain very similar to that at Tacoma is administered in an entirely different manner but with the same purpose in mind. This watershed is completely under the jurisdiction of Seattle, which owns most of the area. Some controlled logging is permitted, but no habitation is allowed

and unauthorized entry is subject to prosecution for trespass. Obviously, the possibility for such stringent measures exists only if ownership of the watershed is vested in the water supply authority, a rare condition where large watersheds are concerned.

Additional examples of the kind of cooperative action that can be taken are found in central Illinois, where the sedimentation of municipal supply reservoirs has been the subject of joint studies by the Illinois Water Survey, the U.S. Soil Conservation Service, and the water departments of the particular cities involved. The most recent of these investigations is one of Lake Springfield, in which the Springfield, Ill., Water, Light, and Power Dept. has taken an active part (*4*).

A typical study consists of a somewhat detailed sedimentation survey of the reservoir to determine the amount, rate, distribution, and nature of the deposits. Also included is an analysis of topography, soil types, land use, land capability, and other factors. These data are correlated with the findings on reservoir sedimentation to develop a watershed control program. At Lake Springfield, it was found that a well-planned program would reduce sedimentation as much as 78 per cent and prolong the useful life of the reservoir by 34 years. Similar studies have been made at Macomb, Havana, Carbondale, Gatesburg, West Frankfurt, and Galva, Ill.

In the opinion of this task group, these Illinois projects represent an exemplary effort on the part of water works men to meet the problem of watershed management and sedimentation. No doubt there are other examples, but they have not been brought to the task group's attention.

The above instances generally involved timbered or cultivated lands with adequate rainfall. The semiarid watershed is usually characterized by sparse and scrubby vegetation of the chaparral type, which has little value other than as watershed cover. For this purpose, it is extremely valuable. The principal causes of the destruction of this cover are fire and road or camp site construction, both resulting largely from recreational use of the areas. Some loss of cover is due to burning or clearing to increase the growth of grasses for grazing.

Precipitation in semiarid areas follows a cyclonic pattern, with the relatively meager annual rainfall occurring in a few heavy storms. This combination of low annual rainfall and attendant sparse vegetation with high momentary rainfall rates leads to heavy runoff that is beyond the capability of the vegetal cover to control. In these regions, therefore, erosion control of gullies depends heavily on engineering measures such as debris basins, diversion dikes, and catchment areas.

The examples cited illustrate the wide scope of watershed erosion problems and the influence of local conditions of topography, climate, and land use. It is important to note that the solution invariably lies in modification of the runoff hydrograph to reduce the eroding and load-carrying capacity of the stream to a minimum.

Conclusions and Recommendations

The task group believes that the following observations and recommendations are pertinent to the problem of watershed protection and erosion control at the present time:

1. Technical progress in the field of watershed ecology and erosion control has been rapidly advanced by the agencies specifically designed for this type of work. It is not considered desirable that the water works industry engage

in research in this field, except in connection with very specific individual problems.

2. Many water works operators have still to attain a proper level of concern with watershed management for erosion control. It is essential that developments in the field be studied and applied as a part of well-rounded water works management, at least to the extent of thorough cooperation with soil conservation agencies.

3. Legislation now existing or under consideration at federal, state, and local levels relates directly to watershed management and soil erosion. It is important that water works management follow such legislative developments and exert its influence on behalf of public water supplies. Fortunately, legislation designed to control watershed use in favor of one interested group is usually beneficial to all groups.

4. On almost all types of watershed, specific investigations can be made that will indicate: [1] the extent of the erosion and sedimentation problem, if it exists; and [2] the best remedial course to follow. A few such investigations are:

a. Reservoir sedimentation surveys, such as are now being conducted in Illinois.

b. Stream sediment load surveys. These indicate rates of accretion of reservoir sediments where prior sedimentation surveys in the reservoir are not available. They also reveal the effectiveness of watershed control measures.

c. Economic studies, to indicate, for particular situations, the relative merit and economy of erosion control measures and enlargement of reservoir capacity (or new reservoir construction) where erosion control, as such, is the only watershed management problem.

d. Land use surveys, to determine particularly the extent of misuse of watershed lands that might lead to erosion and sedimentation.

These and other investigations can be carried out by water works management either alone or in conjunction with the Soil Conservation Service and other agencies. The importance of cooperation with these groups can hardly be over emphasized. Where investigations are made or data accumulated that will contribute to the store of knowledge of the sedimentation problem, it is essential that the information be forwarded to this task group for dissemination to the industry in general. It is the function of this group to weigh the value of such contributions and to coordinate them with other findings, a task that obviously cannot be accomplished unless the data are received.

Acknowledgment

The task group wishes to acknowledge the invaluable help of Robert V. Phillips, Staff Engr., Los Angeles Dept. of Water and Power, in the preparation of this report.

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APPENDIX

Bibliography on Erosion Control and Watershed Management

Because an adequate knowledge of developments in erosion control and watershed management is considered essential to enlightened administration in these fields, Task Group E3.A—Watershed Protection and Erosion Control has prepared a bibliography on the subject. This list is by no means complete but is believed to be representative of the work on watershed management published since 1939.

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Effects of Beetle Infestations on Watersheds

By D. S. Nordwall

A paper presented on May 14, 1953, at the Annual Conference, Grand Rapids, Mich., by D. S. Nordwall, Asst. Regional Forester, Forest Service, U.S. Dept. of Agriculture, Denver, Colo.

THE major river systems of the West have their sources in the national forests. Most of the water which feeds these systems is produced above el 8,000, largely in the form of snow. For example, although only 19 per cent of the Colorado River drainage area in the United States is within the national forests, these lands produce 56 per cent of the total annual flow. Similarly, only 9 per cent of the Missouri River drainage area above Fort Randall Dam, S.D., is within the national forests, but this portion yields 37 per cent of the total annual flow.

The basic legislation establishing the national forests gave as a principal reason for their being in public ownership the need to make certain of "favorable conditions of water flows." No one knows precisely how much the national forests are worth to the people of the United States as major sources of clean, usable water. Estimates by some competent authorities set a figure, based on current water prices, of hundreds of millions of dollars a year. The value of certain national forest watersheds for water yield alone is estimated at $2,000 per acre. In a rapidly growing western city, a new supplemental storage, supply, and distribution system required a capital investment of $147 per acre-foot produced. Allowing 4 per cent interest on the investment, combined depreciation, operation, and maintenance expenses result in a unit annual cost of $9.00 per acre-foot of additional water obtained. Municipal engineers estimate that future planned extensions will have a comparable unit cost.

Dollar value alone, however, is a poor criterion. Water is a basic necessity, worth whatever must be paid for it. There are other ways of measuring the value of this resource from the national forests. More than 1,800 communities, some of them cities of several hundred thousand population, are dependent on national forest watersheds for their domestic and industrial supplies. Thousands more are indirectly dependent on the forests. The majority of the principal irrigated farm developments of the West depend on the national forests for their water. More than 600 hydroelectric power developments, including practically all of the major projects in the western states, depend on water from the national forests.

Under the multiple-use concept of administering the national forests, the production of usable water is a dominant consideration in the management of the other resources, such as timber, grazing land, and recreational facilities. All of these resources are interrelated, and conditions that affect one influence

the rest as well. Thus, forest fires, insect plagues, and disease epidemics can and do have a pronounced effect on water production in particular and forest land management in general. The case history of a recent invasion of forest insect hordes will illustrate the long-range impact of such catastrophes on water as well as on the many other forest resources.

Beetle Infestation

The bark beetles (*Dendroctonus*) in Colorado were first discovered—or, at least, identified as such—near Manitou and Blackhawk in 1875. In 1905, on the south slopes of Pikes Peak, evidence of an infestation that had occurred in the 1850's was found. In the meantime fire had swept the area, and, to the casual observer, it appeared that the barren conditions were due to the latter event. After creation of the Pike National Forest in 1892, however, beetle galleries were discovered on the trunks of dead trees. These, together with other evidence, indicated that the trees were dead before the fire occurred. That conclusion is supported by the intense burn and the unusually complete destruction and denudation that resulted. It is further confirmed by more recent experiences and observations that fires almost invariably follow within 3–15 years after any big timber kill, whether the destruction is due to insects, wind throw, or some other cause. An identical cycle was experienced approximately 75 years ago on the Grand Mesa in western Colorado and, during various prepioneer periods, in the Lincoln Forest of New Mexico, the Manti Forest in Utah, and Yellowstone National Park in Wyoming.

It should be explained that certain amounts of insect activity, and tree diseases, too, are common throughout timbered areas, especially in overmature and defective trees. If the stands as a whole are healthy, however, they have a natural resistance that overcomes ordinary enemies. In this respect, trees are comparable to people, who, if well nourished and healthy, resist and throw off a great variety of illnesses and irritants constantly encountered in life. It is the outbreaks of epidemic proportions, then, that are of major concern and require special consideration and treatment.

Although early infestations caused widespread damage, probably none was more destructive than the recent Colorado Engelmann spruce beetle infestation. On June 15, 1939, an unusually high wind that persisted for more than 24 hours uprooted thousands of trees from the ground, which had been left soft and spongy by melting snows in the White River National Forest on the slopes west of the Continental Divide. The weakened and dying trees presented an ideal environment for the bark beetles that had been present in normal numbers. Conditions were so favorable, in fact, that the beetles increased at a phenomenal rate, reaching epidemic proportions by 1941. Salvage cutting was started immediately as a control measure, wherever logging was possible. Beetle broods in areas inaccessible for logging continued to spread, however. Prevailing southwesterly winds carried adult insects into more and more remote areas. By 1943 the infestation had increased so greatly that the beetles were attacking trees of all ages, but, with a nation at war, labor and equipment shortages made specific control measures impossible.

To complicate the situation, knowledge of the life history of and control methods for this type of beetle was lacking. Through research promptly undertaken, it was learned that the beetle had an unusual 2-year life cycle and that the only effective control was through chemical treatment of the bark of each infested tree.

From 1943 to 1948 the beetles moved generally to the northeast, spreading over vast areas of the Colorado national forests and killing 95–100 per cent of the timber in their path. The heaviest damage was in the White River National Forest, where the kill amounted to 919,000,000 fbm in a single year (1944). Strangely, the northeasterly movement stopped in 1949, when a freak change of weather brought winds out of the northwest at the time of the beetle flights. As a result, the infestation spread to the south and east, reaching the Arapaho Forest.

Control and Salvage Operations

Since 1941 a total of approximately 4.3 bil fbm of timber has been killed in all the Colorado national forests. The infestation covers approximately 3,000,000 acres, and the lumber destroyed would be sufficient to build 715,000 five-room houses. To appreciate the magnitude of the control job, it must be kept in mind that much of the infestation occurs in high, rugged, inaccessible mountain country in which the transportation of equipment, chemicals, and other materials is extremely difficult and costly. The control operation finally authorized by Congress in 1950 was truly gigantic, fully comparable to a large military operation. For example, it was necessary to build 421 miles of new roads and do road improvement work on an additional 125 miles in order to gain access to camp sites and treatment areas. At the height of the campaign, more than 1,000 men were employed and fourteen camps were established. More than 200 trucks were required for moving men, equipment, and insecticide to treatment areas. In addition, approximately 20 "pack strings" of horses and mules were used for transportation to rough back-country beyond the reach of roads. Nearly 1,250,000 trees were treated at a cost of $3,307,000, or $2.71 per tree.

Concurrent with the control job, a most important consideration has been the salvage of the greatest possible amount of destroyed timber. Unfortunately, the remoteness of large affected areas and the rapid deterioration of the wood (for lumber, but not for pulp use) sharply limit the extent to which such material can be removed and marketed. Many inducements, including special stumpage rates, assistance in road building, and similar measures, are being taken to speed the salvage. As much wood as they can use is given to local settlers and ranchers, so that it will not go to waste. Under normal conditions in the past, of course, it was usually possible to salvage small areas of dead timber by these various means. In the present situation, however, it has been feasible to dispose of only a small fraction of disaster-killed trees. On the brighter side, combined efforts of government and industry are showing encouraging results. The growing scarcity of timber has increased prices, making it profitable to utilize wood material that was rejected a few years ago. New processes permit the use of wood that formerly went to waste. Many new and better roads have been built, and transportation equipment has

been greatly improved in recent years. Taking advantage of these and related developments, various groups have concentrated on finding methods of salvaging the beetle-killed timber in Colorado. These efforts include research on pulpwood processing by the Forest Products Lab., Madison, Wis.; negotiations for special railroad shipping rates; and investigations on the feasibility of establishing pulp mills in Colorado. Although the results have not been spectacular, a measure of success has been attained. As an example, 4,000 carloads of pulpwood have been shipped to mills in the Great Lakes states. Private groups have been endeavoring to organize a corporation to build processing mills. One of these went so far as to bid on 4,500,000 cords of pulpwood—a large proportion of which was beetle-killed spruce—offered for sale by the Forest Service. This project did not materialize because of financing difficulties, but other concerns are still showing strong interest in the venture.

Watershed Problem

In the infested portions of the Colorado national forests, where altitudes range from 9,000 to 10,500 ft, 60–70 per cent of the annual precipitation is deposited in the form of snow. Storms are generally small and frequent. As a result, through interception and evaporation from trees in heavy, green spruce stands, the losses of water are substantially larger than in many other regions.

For several years following an insect infestation most of the killed trees will remain standing. The protective cover of needles and mulch on the ground will not be appreciably disturbed. In fact, as the dead trees drop their needles, the mat or cushion on the ground will be temporarily increased. A major change in snow deposition takes place, however. The skeleton trees remaining after the needles have fallen lose most of their capacity to intercept snow and rain, so that more moisture reaches the ground and a correspondingly greater amount of water is available for stream flow. This conclusion is supported by experiments conducted at Fraser, Colo., by the Rocky Mountain Experiment Station, indicating that as much as 30 per cent more water reaches the ground from an opened canopy than from adjacent areas with dense tree cover. Of primary importance, then, is the determination of the relative benefits from the increased water yield compared with the long-range effects on water supply, as well as on other resources.

Since 1937 the water content of the snow pack in open parks on the White River plateau has averaged approximately 18 in. The heavy timber has shaded the snow, causing the runoff to be more gradual and to continue over a longer period. With the removal of the canopy, an increase of up to 25 per cent in snow pack—and resulting water—can be expected, and, with it, a faster runoff of higher volumes in a shorter period. On the steeper slopes, this surplus, when added to an already saturated soil, may have serious consequences, producing erosion channels at the higher elevations and flood stages in the lower valleys. For example, comparative water yield studies on two watersheds, one inside and one outside the beetle-killed area, showed an annual increase of 18 per cent in runoff from the infested drainage area over the uninfested one, beginning in 1947.

The practical effects of such changes in watershed behavior can prove far-reaching and costly, as disasters of this type on a municipal watershed can produce a heavier early spring flow and a correspondingly smaller late-summer and fall discharge. As a result, a proportionately larger and more costly reservoir would be required to store the early water and insure adequate capacity to compensate for the subnormal later flow. Increased debris and silt loads from denuded watersheds further intensify the problem for cities and other water users. Even from a purely economic standpoint the cost of preventing such calamities to the watershed will prove a wise investment, compared with the expensive restorative and structural measures that may be needed subsequently.

After a period of years—estimates vary on the length of time—it may be expected that a more nearly normal forest cover will become reestablished and the factors previously discussed will be largely overcome. In the meantime some drying out of the ground surface may be expected from the removal of the overstory, resulting in a lowered rate of water absorption by the soil and accentuating the danger of fast and heavy discharge of waters from the zone for a number of years.

The utilization of other forest resources is also materially affected. Summer grazing of sheep and cattle becomes increasingly difficult as the killed trees fall to the ground and block normal routes of movement. Prior to the beetle epidemic the high spruce forests and parks of the White River plateau lured hundreds of visitors annually to pack or hike into this outstanding wilderness, to camp, hunt, fish, or merely enjoy its grandeur. The gaunt, ghostlike snags that have replaced the verdant spruce have transformed a recreation paradise into a sickening spectacle.

Forest Fires

Pending reestablishment of a suitable forest cover, water yields will be very materially influenced by the occurrence of forest fires. Of course, fires have always been present and probably always will be. Even if man-caused fires might some day be reduced to a satisfactory minimum, lightning will still be a factor in the spruce forests. But fire damage and control problems, when a natural stand of green trees is involved, are greatly different from those presented by a mountainside covered with dead timber. Although there are many noteworthy exceptions, forest fires are ordinarily confined to the fallen twigs, needles, and other fuels on the forest floor. Their spread is relatively slow; the small kindling-like material usually does not make an intensely hot fire, and it burns out quickly. Every year thousands of such fires are stopped by forest rangers and their crews before they cover an area as large as a city lot. The public is not even aware of such fires.

A widespread infestation of bark beetles, however, entails a vastly more serious fire hazard. Green trees die by the hundreds of thousands or even by the millions. Soon they begin falling, and, as time goes on, a jumbled mass of criss-crossed tree stems is formed, representing millions of cords of dry wood, loosely scattered on the ground and ranging in thickness from 1 to 5 ft. When a fire gets started in such an accumulation of heavy fuel, it does not behave as it would in a layer of needles.

From a control standpoint, the accessibility problems are multiplied. The downfalls cannot be penetrated by horses, much less by trucks carrying men and fire-fighting equipment. The only way to enter is on foot, a slow and torturous process. Instead of a light fire that burns out in a few minutes, the piled-up fuel burns with terrific heat for many hours or days. The intensity of the heat, combined with access and control obstacles, means larger burned areas and greater destruction of all the resources present.

The long-range effects of fires in beetle-devastated watersheds are also much different from those on normal forest lands. Fires in needles or other light fuels usually kill only small trees of seedling or sapling size, most of the larger trees being spared. Soon a new crop of needles is dropped and a protective ground cover begins to accumulate. The topsoil suffers little damage, and most of the organic matter remains intact. As seeds of grasses, weeds, shrubs, or trees—particularly seeds that have been shallowly buried—are frequently not destroyed by light fires, they soon germinate and quickly help to reestablish a ground cover. It is by no means intended to minimize the danger of small fires in green timber. On the contrary, every effort is made to confine fires to the smallest possible size, because every one is a potential conflagration. The seriousness of such fires is small only by comparison with the intensely hot and long-lasting ones that follow beetle infestations, burning all the humus, killing any remaining trees or other vegetation, and destroying seeds that may be under the surface. Finally the organic matter near the surface of the ground is cooked and the land is rendered sterile. The burned areas are left naked and unprotected. With an increased snow pack and cloudburst storms, the water no longer falls on a cushion of vegetation and humus, to seep away gradually. Rather it falls directly on bare, exposed ground, loosening the topsoil, and then immediately flowing off the surface in mud-laden streams and accumulating into quick floods, at the same time eroding the slopes.

Under such conditions, the water yielded is muddy and practically unusable, the flood flows are uncontrollable and the offsite flood and silting damage is extensive. In addition, the scorched soil cannot be healed readily through the growth of natural, or even artificial, vegetation. The land on the south slopes of Pikes Peak, where, as previously mentioned, a terrific fire occurred a few years after beetles killed the timber a century ago, is still far from restored. Revegetation is partial and spotty, and adequate land recovery is yet 100 years in the future. In the meantime the watershed, a source of supply for Colorado Springs, Colo., a city of 50,000 people, cannot function with maximum effectiveness.

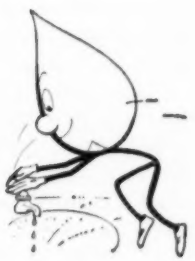
Conclusion

As indicated at the outset, history reveals that practically all widespread beetle infestations have been followed by fires of the devastating kind. In the light of what has happened in the past, the U.S. Forest Service is redoubling its efforts, not only to salvage as much of the usable insect-killed timber as possible, but also to clean up the debris and unusable logs. Particular attention will be given to removing trees that fall across roads. Fire control

will be stepped up in every way practicable, in order to get trained, well-equipped crews to every fire with a minimum of delay. Only by such means can fires be reached quickly and stopped while they are small and relatively easy to control.

The insect control project has provided methods for combating this scourge that otherwise would have presented a hopeless situation. The improved general road system furnishes greater accessibility to large blocks of killed timber. Many areas formerly accessible only by long horse trips can now be reached by truck. The steadily growing shortage of wood materials, the increasing need for timber products, and the development of new uses and processing techniques, combined with improved transportation facilities, make it possible to utilize timber that could not have been employed a few years ago.

Through the help of the Bureau of Entomology and Plant Quarantine of the U.S. Dept. of Agriculture and through its own experience, the Forest Service has learned a great deal about insect control measures, including the life cycle and habits of the beetles and effective chemicals and techniques of treatment. All of these advances in technology and general knowledge, however, are relatively ineffective unless an enlightened public demands aggressive action and demonstrates a willingness to finance it. Resources of tremendous value to this and succeeding generations are at stake. Tragic past experience is clear evidence that the time to combat forest insect infestations, and forest fires, is while they are small.



Copper Catalysis for Manganese Oxidation

By F. L. Futral and Robert S. Ingols

A paper presented on Mar. 24, 1953, at the Southeastern Section Meeting, Macon, Ga., by F. L. Futral, Supt. of Water Treatment, Newnan, Ga., and Robert S. Ingols, Research Prof., Eng. Experiment Station, Georgia Inst. of Technology, Atlanta, Ga.

Experience at Newnan—*F. L. Futral*

THE water treatment plant at Newnan, Ga., is located on a small stream that has been impounded to create a reservoir with a surface area of approximately 40 acres and a capacity of approximately 140 mil gal. The water is extremely soft and is typical of the surface waters of the Piedmont Plateau area. With a full reservoir, the water depth at the intake tower, just above the dam, is 42 ft. Water may be drawn from either of two openings, one at the 15-ft and the other at the 35-ft level.

Sections of the filter plant, which has a total rated capacity of 3 mgd, were built at different times, and the installation consists of two almost separate plants. Each has rapid mixing, with a flocculation period of approximately 45 min, followed by settling for 8 hours. There are three sand filters, each having a capacity of 0.5 mgd, and two filters with capacities of 0.75 mgd. The clearwater storage reservoirs have a capacity of 1.8 mil gal.

Dual chemical-feed equipment permits the two mixing and settling basins to be operated simultaneously but with different treatment techniques, if desired. Also, settled water may be applied to certain filters directly from one or the other of the settling basins, or the settled water from the two basins may be mixed before filtering.

The raw water from the bottom of the reservoir is typical of the hypolimnion, frequently having the following characteristics: pH, 6.4–6.8; alkalinity, approximately 35 ppm; carbon dioxide, approximately 25 ppm; color, 10–40 ppm; dissolved oxygen, none. Iron may be as high as 30 ppm and manganese 4.0 ppm or more. At the same time water taken from the upper intake may have a pH of 7.0; alkalinity, 18 ppm; carbon dioxide, 3–5 ppm; dissolved oxygen, 3–7 ppm; iron, less than 4.0 ppm; manganese, less than 1.0 ppm. When seasonal turnovers take place, the iron and manganese content of the upper strata may be much higher.

Effect of Copper Sulfate

Because, during the spring and summer, algae in the pond grow rapidly, it frequently becomes necessary to control the quantity of algae developing along the shore by the use of copper sulfate. After treatment with this chemical, the appearance of the water in the pond is markedly changed. There is a disappearance of the yellow color and a development of a green or blue color, which is indicative of more than the presence of the copper ion.

It was noted that the ability to remove iron and manganese from the water during treatment is frequently better at one time than at another. An examination of the records showed that improved removal of manganese generally followed the application of copper sulfate to the reservoir for the control of algae. Acting on this observation, a program was set up to determine the amount of copper sulfate that could be added in the mixing chamber along with alum (aluminum sulfate) and chlorine.

It was found that 0.5 ppm copper sulfate would give very low manganese residuals, while more copper sulfate was unnecessary. On the basis of this information, copper sulfate was added to the mixing chamber. Manganese concentrations on the order of 0.01–0.05 ppm were obtained in the filtered water. This procedure was started in the spring of 1950 and has been used successfully since that time at each turnover season.

It should be understood that the oxidation of the manganese is carried out in the presence of both a free chlorine residual and oxygen which is supplied to the water with the treatment chemicals. It is common practice at this plant to add enough lime at the end of the flocculation chamber to raise the pH to 9.5 or 10.0, in order to assure complete oxidation of the manganese and to render the oxygen more effective in this reaction. The lime is allowed to flow over a small piece of copper gutter from the end of a pipe into the center of the flow of water in the last flume of the mixing chamber. During a routine inspection of this operation, the copper gutter fell into the flume and was allowed to stay on the bottom for some time. When the chamber was drained, the copper metal was found to be covered with a coating of manganese dioxide crystals. This condition of the copper is the same as that reported by some operators in Georgia, where water meter parts or bronze pump impellers have become coated with manganese dioxide.

Conclusion

The results indicate that the use of copper sulfate definitely improves the activity of either chlorine or oxygen in the reduction of manganese in this plant.

The presence of manganese dioxide on a piece of metallic copper in a water that should normally oxidize the manganese seems to corroborate the theory that copper sulfate can aid the oxidation of manganese.

Theoretical Considerations—*Robert S. Ingols*

The literature records that others have studied the role of copper sulfate in the oxidation of manganese. Van der Waal (*1*) reported that copper sulfate added to well water which was then forced through a contact sand filter by the use of an air ejector greatly aided in the reduction of the manganese content of the water. It was shown that, after a period of time, the use of copper sulfate could be discontinued and the filter would function in the same way as when copper sulfate was added. The explanation was that copper which had plated on the sand grains then functioned in the same way as the copper sulfate had previously.

From theoretical considerations, it can be shown that hypochlorous acid is able to oxidize the manganous ion to

the manganic ion at any pH, provided that there are no interfering substances, such as the chloride ion in excess of 35 ppm or a large amount of organic matter.

Oxygen can oxidize the manganous ion when the pH is high enough and the time is adequate. A long contact period with chlorine has been found very successful for the oxidation of manganous ion in Milledgeville, Ga. Chlorine is now added to the inlet of the storage reservoir, where 48-hour storage provides sufficient time for the oxidation. It is believed that copper used with chlorine or oxygen plays the role of a true catalyst in that it can reduce the time necessary for the oxidation of manganese by either of these two materials.

The use of copper sheets has been tried in a clear well where the water has a pH of 8.5; the manganic oxide crystals begin to form in a very short time and are coated on the copper, either in a thin film over the entire surface or in small nodules characteristic of pitting corrosion.

In another situation, it has been the author's experience that manganese will precipitate out in copper tube water heaters if the water contains a large amount of manganese. The accumulation of the crystals may lead to stoppage of the tubes and to periodic discharge of small amounts to the heated water.

It has been observed also that Monel metal will retain crystals of the manganic oxide. This phenomenon occurred on the upstream face of a flash steam condenser (multiple-tube, single-pass water heater).

This very brief article has been written, not because it is a complete research picture, but because it is felt that water plant operators troubled with the problem of manganese removal might wish to consider the use of copper as a catalyst in the oxidation of manganese. Copper will not reduce the amount of chlorine or air required but, when added at the proper point, will change the rate at which these materials can function.

Conclusion

Either copper or the cupric ion will increase the rate of oxidation of the manganous ion to the manganic ion by the chlorine or oxygen present in a water. The same catalytic action is also true for Monel metal.

Reference

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Cast-Iron Pipe Coatings and Corrosion

By John R. Baylis

A paper presented on May 12, 1953, at the Annual Conference, Grand Rapids, Mich., by John R. Baylis, Engr. of Water Purif., Bureau of Eng., Chicago.

THIS is not a paper telling the industry how to coat cast-iron pipe. It merely relates what has happened to the coal-tar coating inside some of the pipes in the water system of Chicago, together with a few observations made in several other cities. Also, it will show how natural coatings are built up on pipe surfaces in old water pipes. For many years the cast-iron pipe manufacturer relied mainly on hot coal-tar dipping to protect the pipe. About 1925 Portland cement-mortar lined pipe began to be used. Some consulting engineers say that their specifications now call mostly for mortar-lined pipe, especially for jobs in the eastern and southeastern part of the United States, where the water is not very hard. A number of cities in the Midwest, and perhaps in other localities, still specify coal-tar coated pipe.

Part of the piping in many cities has been in service more than 50 years. Chicago is just now boasting of cast-iron pipe in service 100 years. Soon many cities will be making the same claim. No one has apparently found a paint or coal-tar coating on any of the 100-year-old pipes. None was found in Chicago, nor was there much pipe corrosion. This is not to imply that the cast iron made 100 years ago was noncorrodible. Cities with corrosive waters have been forced to take account of the condition of their cast-iron mains after a much shorter period of service.

As the present article is largely a continuation of a recently published paper by the author (*1*), a brief digest of certain parts of the latter would be helpful to a more thorough understanding of what follows.

The coal-tar coating in a few lengths of 30-in. cast-iron pipe removed from the ground after 30 years of service was found to be in a disintegrated and blistered condition. The coal tar had been largely washed away from a strip at the bottom of the pipe 6–12 in. wide. On each side of the bottom strip, rust tubercles generally were present. The upper half of the pipe contained fewer tubercles.

Practically all tubercles were dormant and gave no evidence of having been active within the past few years. The tubercles in these lengths of pipe were mostly cone shaped, enlarging in diameter at the growing end as the tubercle lengthened. The cone-shaped tubercles belong to the spicule class, in which there often is fingerlike growth of the tubercle with no increase in diameter.

Disintegration of the coal tar begins to occur in some pipes after approximately 20 years of service, while in

others it takes longer. Pipes with the coal-tar coating in good condition after 50 years of service have been found. Where there is deterioration, the coal tar becomes brittle and disintegrates into very small particles. Much of it does not wash away, being held by some kind of binding material at the surface of the coal tar. A blistered coating is shown in Fig. 1.

The absence of the coal-tar coating at the bottom of the pipe may be caused

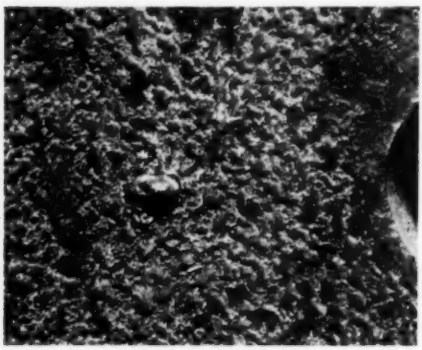


Fig. 1. Blistered Coal-Tar Coating

When the coating deteriorates, it becomes brittle and disintegrates into very small particles.

by suspended objects, such as sand and loose rust tubercles, rubbing along it.

Form of Tubercles

The theory of corrosion is well covered in the technical literature. Nothing was found in the present investigation that is contrary to the theory. In two articles published in 1926, the author (*2, 3*) described the growth of tubercles with corrosion pits in the metal underneath. The first stage in the formation of tubercles is the building of dome-shaped, soft, porous precipitates of ferric hydroxide. The domes may be extremely small or reach considerable size. Then each dome begins to form a hard crust of oxide of iron, which starts next to the metal wall and gradually extends over the entire dome.

Dissolved oxygen in the water plays an important part in the formation of the porous precipitate. Iron must go into solution where water is in contact with the metal surface, diffuse through the precipitate, come in contact with dissolved oxygen in the water, precipitate as ferric hydroxide, then be attracted back to the corrosion area, apparently by magnetic force. The free-floating pieces of ferric hydroxide generally attach themselves to the ends of the fibrous material, making the fibers still longer.

This lengthening of fibers continues until the corrosion rate is slowed to where the dissolved-oxygen zone extends to the surface of the dome-shaped precipitate. The corrosion rate at first must be so rapid that the dissolved oxygen in the water surrounding the corrosion spot is used up in oxidizing the iron and the hydrogen, and the soluble iron is required to diffuse outside of the attached rust before being precipitated. After the accumulation of precipitate has become thick enough to slow the travel of soluble metal, the dissolved-oxygen zone extends to the surface of the precipitate and begins to precipitate ferric iron back of the ends of the fibrous material. The precipitated material then cannot get to the ends of the fibers to keep extending them in length.

The formation of the crust over the porous material represents the second stage of tubercle formation. Corrosion continues at the metal surface, with

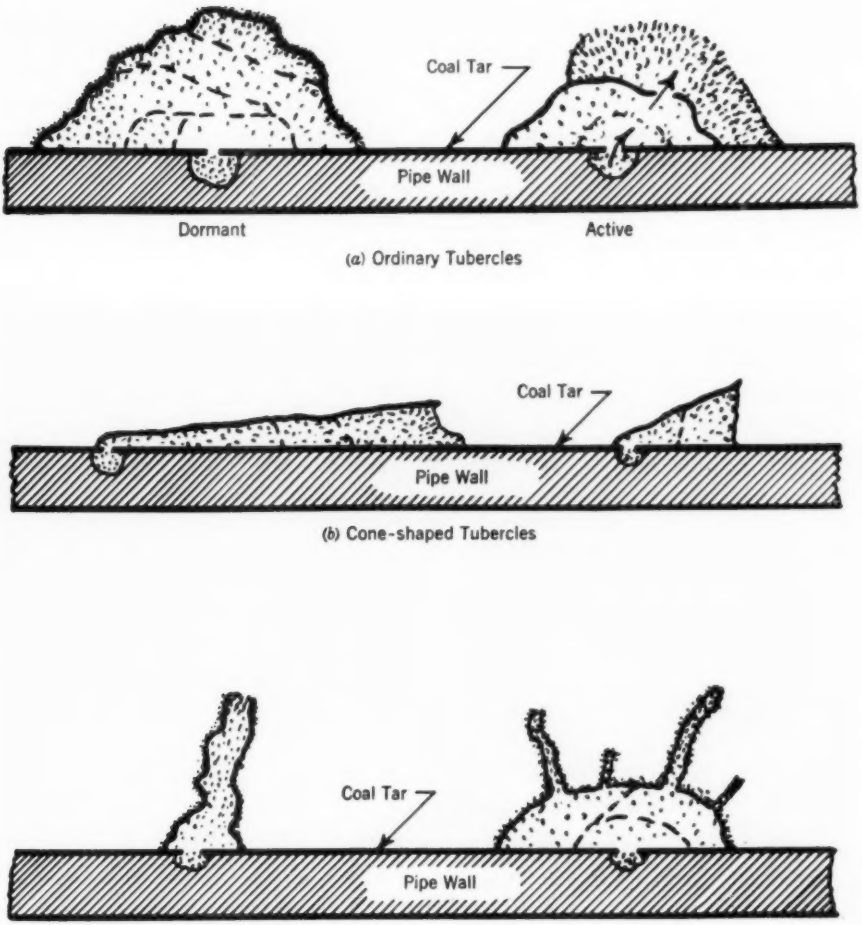


Fig. 2. Various Forms of Tubercles

Compare the photographs in Fig. 3, 4, and 6.

much of the precipitated iron being used up in building a hard surface membrane over the porous material. Most likely, there is a gradual slowing of the corrosion rate until it stops completely, or until the surface membrane breaks and produces more porous and fibrous precipitate. The dormant tubercle has an accumulation of iron salts, such as ferrous sulfate, ready to diffuse out into the water once a hole forms in the crust.

Figure 2 illustrates the shape of some of the tubercles encountered in the cast-iron pipes in Chicago. The top sketch, Fig. 2a, shows ordinary tubercles

where the flow of water is not great. Figure 3 is a photograph of such tubercles in a 6-in. water main. The tubercle on the left in Fig. 2a has grown to large size in a series of dormant and active periods and is now illustrated in the dormant state. The one on the right is shown in the active state, with a film starting to form to make it inactive when the film covers the newly

in tubercles, but, in such tubercles as have been examined, the pH was too low for ferrous carbonate to exist. Ferrous carbonate increases in solubility below pH 8.0. The pH of the liquid inside of active tubercles generally is less than 6.5, regardless of the pH of the outside water. In dormant tubercles, the pH is generally between 6.5 and 7.0.

Fig. 3. Tubercles in 6-in. Pipe

These tubercles are of the type illustrated in Fig. 2a.

Fig. 4. Cone-shaped Tubercles

The shape of these tubercles, in a 30-in. pipe, was influenced by flow velocity.

precipitated material. If the water flows at considerable velocity, the deposited material is washed away.

During the period of formation of the impervious film at the outer surface of the porous material, negative ions are concentrated within the tubercle. Sulfate ions generally predominate, but chloride ions also concentrate in some tubercles. It is not impossible to conceive of carbonates being concentrated

As stated, a concentration of soluble iron salts exists inside tubercles, and, when a break occurs, some of this soluble iron diffuses into the water outside the tubercle and is precipitated by the alkali in the water. Also, it becomes oxidized to a ferric state by dissolved oxygen. As long as the soluble iron salts are diffusing rapidly from the tubercle to the water outside, the dissolved-oxygen zone in the water is kept

away from the precipitate that is forming.

Figures 2b and 4 illustrate cone-shaped tubercles that are formed where the flow of water in the pipe influences the shape. Very likely, the flow has to be moderately high. Although the flow of water keeps washing away the iron precipitate, a little of it deposits on the pipe wall around the hole. The precipitate, instead of growing straight out, becomes pointed downstream, the flow of water preventing a deposit on the upstream side. When the flow is not very rapid, the tubercle forms somewhat as shown in the right-hand sketch of Fig. 2b. With high velocity in the pipe, the deposit forms more closely to the pipe wall, somewhat as shown in the left-hand sketch. A still higher flow may prevent, or almost prevent, any deposit on the pipe wall. The flow of water is disturbed at the downstream end of the tubercle and allows a gradual deposit of the precipitate as the hard layer extends, with only a small portion of the precipitate depositing and the balance being carried away in the water.

The significance of the influence of velocity on tuberculation has not been taken into consideration heretofore by most water supply engineers. If they studied the formation of tubercles as described in the publications to which reference has been made, they would have a better understanding of the matter. A tubercle cannot push out from the metal surface. It can be built up only from free-floating material produced by chemical reaction with the alkali and dissolved oxygen in the water and then attracted back to the tubercle surface. A high flow velocity will keep washing the precipitate away. Once a hard membrane has formed over the soft and porous precipitate, however, no force of water likely to be applied will wash it away.

In the cone-shaped tubercles, the apex of the cone is at the place where the pipe is being attacked. The acid solution within the tubercle may later cause holes in the coal tar where the tubercle is attached to the pipe wall.

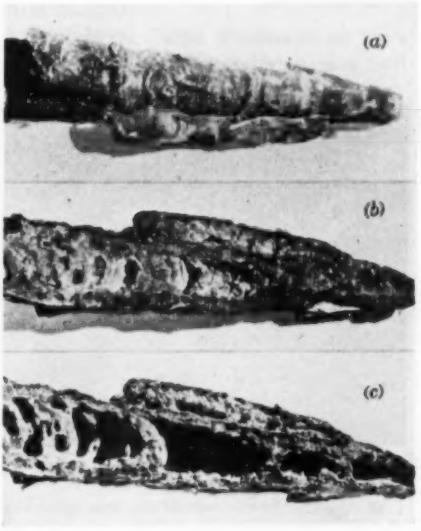


Fig. 5. Large Cone-shaped Tubercle

Key: (a) outside of tubercle; (b) side of tubercle against pipe wall; (c) view of tubercle with part of soft material removed.

The tubercle shown in Fig. 5, removed from a 36-in. pipe after 41 years of service, was 4¼ in. in length. Other tubercles, 8–10 in. long, were found in this pipeline but could not be removed in one piece. Figure 5a shows the side of the tubercle that was exposed to the water. The side next to the pipe wall can be seen in Fig. 5b, while Fig. 5c is a view of the tubercle with the very

soft material removed from the inside. The veins visible across the tubercle represent dormant stages. There is evidence of more veins, not so hard, that were broken loose in removing the soft portion. A new tubercle, approximately 2 in. in length, may be noted along the lower side of the main tubercle. The cause was a hole breaking through the thick wall approximately ¾ in. from the apex. Examination of Fig. 5a reveals a small breakthrough that originated not far from the apex.

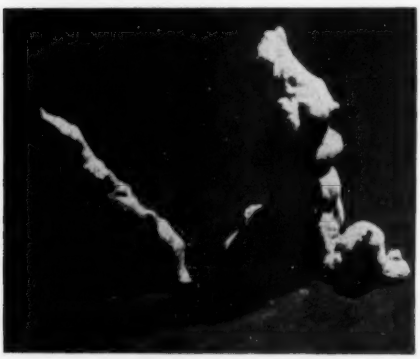


Fig. 6. Two Spicule Tubercles

The spicule builds up at such a rate that the membrane cannot form over the end until a long finger has been produced.

Several other very small breaks can be detected.

The spicule or finger tubercle is the most difficult to describe. It may be as much as ¾ in. in diameter or less than ⅛ in. The very small ones are generally not longer than ½–1 in., while the larger ones may be 2–3 in. in length. Figure 2c is an attempt to illustrate the shape of such tubercles. The spicules do not vary greatly in diameter but often are somewhat larger at the base than at the growing end. They form apparently only in water close to the saturation equilibrium of calcium carbonate. In flowing water, they are found sloping downstream.

Figure 6 is a photograph of two spicule tubercles. The coating on the outside wall of the tubercle is the same hard material as the membrane over dormant tubercles. The spicule keeps building up at such a rate that the membrane cannot form over the end until a long finger has been produced.

Inside Pipe Surfaces

A study was made of the condition of the inside surfaces of a few of the older Chicago pipelines where no coal tar appeared to be present. As most of these pipes are of great age, there is no record of whether they were coated at the time of manufacture. It is believed that they were, however, and that the coating disappeared years ago. Little corrosion was found in the pipes. No chemical analyses of the pipe metal have been attempted, and it may be possible that the metal composition is the reason for the lack of corrosion, but the explanation is thought to lie elsewhere. The results of the examination of several pieces of old pipe will be given.

Figure 7 shows the inside surface of a 4-in. cutout on a 6-in. pipe at Clinton and Eighteenth streets, laid in 1886. The surface appears very rough, and it was rougher than most of the pipes examined. A low-power microscope indicated the surface to be nearly covered with sand grains, which may have come from the molding sand. They are bound to the iron quite firmly, and it does not seem possible that they could have become cemented so rigidly as to remain attached after treatment with an acid. In Fig. 8, a photomicrograph, the arrow points to a spot where the iron was corroded, with the forma-

tion of a very small tubercle. Before being photographed, the surface was cleaned slightly by placing one drop of dilute hydrochloric acid on it and then washing it off with water after approximately 2 min. There was an ebullition of gas as soon as the acid touched the surface, indicating the presence of carbonates. A photomicrograph of the surface before the acid was added showed the spaces between the sand grains more nearly filled than is apparent in Fig. 8. Calcium carbonate probably deposited over the surface at times of high algae growth, when the lake water was slightly supersaturated with the compound. A section of uncoated cast-iron pipe recently suspended in raw Lake Michigan water produced numerous small tubercles within 40 days.

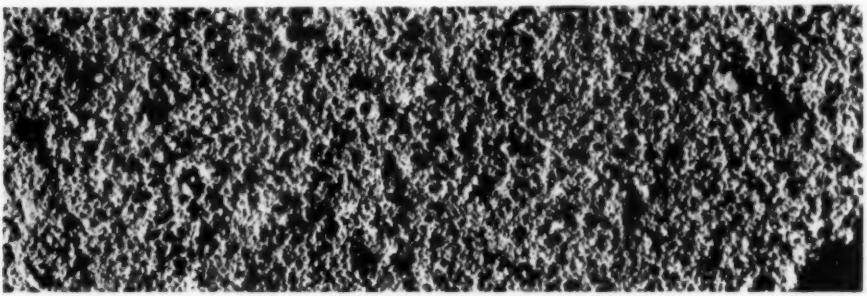


Fig. 7. Inside Surface of 71-year-old Pipe

Microscopic examination showed the surface to be nearly covered with sand grains, perhaps from molding sand.

The cutout piece of pipe shown in Fig. 9 was from a 24-in. water main at Wabash Avenue and Cullerton Street. The pipe was laid before 1871, and the cutout was made in 1951. A few tubercles were present, but they had been dormant for many years. The surface was smooth and had a dark-brown color. A drop of weak hydrochloric acid was placed on the surface, with immediate ebullition of gas, indicating the presence of carbonates. A few sand grains were noticed, but not so many as on the surface of the pipe previously described. Although some tuberculation had occurred, corrosion had stopped almost completely, probably shortly after the pipe was laid. No evidence of a coal-tar coating could be found. Exposed to raw Lake Michigan water, this pipe should be in the same condition 100 years from now.

Figure 10 is a 6-in. cutout on an 8-in. main laid in 1869 at Roosevelt Road and Jefferson Avenue. There was no evidence of a coal-tar coating, and no corrosion spots were found. Some of the molding sand still adhered to the surface of the iron, and the hydrochloric acid test indicated the presence of calcium carbonate. The carbonate coating had smoothed over the sand grains and probably produced a surface with less friction to impede the flow of water.

A 6-in. cutout on a 36-in. main at Taylor Street and Winchester Avenue had a coal-tar coating. To the naked eye, the coating appeared to be in good

condition, and no corrosion was noticed on the inside surface. When examined under the microscope, small blisters and many small corrosion spots were observed. Several corrosion pits were present on the outside surface, although the coal-tar coating was in good condition over most of it. Some piping apparently was given a good coating of coal tar even at that early date.

Fig. 8. Photomicrograph of 71-year-old Pipe

This is the pipe shown in Fig. 7. The arrow points to a corroded spot, where a very small tubercle formed.

Corrosion Tests

To obtain information on the initial corrosion rate of cast iron, 1-ft sections of 4-in. pipe were suspended in raw Lake Michigan water, in chlorinated raw water, and in chlorinated and filtered water. The pieces were suspended with chains, but a section of nonconducting material was fastened to the pipe to prevent any possible flow of electric current.

The pipe sections were suspended in the water Aug. 24, 1952, at a depth of 6–8 ft. Because reservoirs were used as test sites, there was no rapid movement of the water.

The first observation of the condition of the specimens was made Oct. 3, 1952, photographs being taken of the outside and inside of each pipe section. The next observation was made Dec. 3, 1952, or 101 days after the start of the tests. A third observation was made Apr. 6, 1953, or 7.4 months after the start.

The cut ends were not painted and, of course, corroded readily. Corrosion

where the cut was made is not taken into consideration.

After 40 days all uncoated specimens showed corrosion, with the formation of dome-shaped precipitates up to ½ in. in diameter. The coated pieces exhibited only a little corrosion, in a few small spots most of which were barely visible to the eye. All of the rust nodules were very soft, and the crust that covers tubercles had just started to form on some of the rust spots. Each rust spot covered an anodic area where the metallic iron was going into solution.

There was only a small change in the size of the tubercles after 101 days' suspension in the water. A hard membrane had formed over most of them, and it is believed that some corrosion was taking place in the tubercles under the membrane. None of the tubercles showed breaks in the membrane or the formation of a second layer of soft, porous precipitate over the original tubercle. The tubercles which seemed to have grown in size apparently had still been in the process of enlarging at the time of the first examination.

After 7.4 months' exposure to the water, the tubercles appeared almost exactly the same as at 101 days. The membranes over the tubercles, however, were thicker and harder. Corrosion may have stopped in some of them, although a small amount may yet have been taking place. In fact, some of the tubercles still were soft at the top.

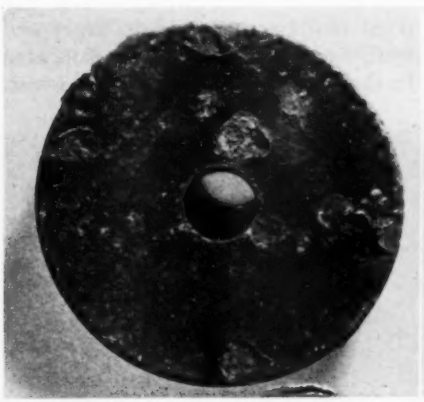


Fig. 9. Uncoated 24-in. Pipe

This pipe, over 80 years old, showed few tubercles, all inactive.

Fig. 10. Uncoated 8-in. Pipe

Laid in 1869, the pipe showed no corrosion on examination.

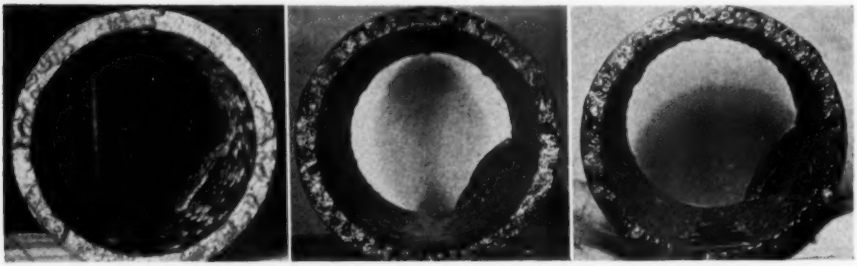
Corrosion may continue at a very slow rate for several years. Many of the dormant tubercles found on the inside of the old mains in Chicago had a crust 0.5–1.0 mm in thickness, while the crust of the tubercles in the test sections after 7.4 months was much thinner.

Raw-Water Specimens

After a specimen of uncoated pipe had been suspended in raw Lake Michigan water for 40 days (Fig. 11a), there were approximately 50 tubercles on the outside of the pipe and approximately

200 on the inside, ranging in size from very small to ½ in. in diameter. After 101 days (Fig. 11b), the tubercles were slightly larger than at 40 days. Some of the large ones were firm to the touch, as were also the smaller ones. There appeared to be no increase in the size of the tubercles after 7.4 months (Fig. 11c), but the crust was thicker. All tubercles had not yet produced a hard membrane. The evidence is that very few new tubercles developed after the first inspection at 40 days.

Coal-tar coated pipe suspended in raw Lake Michigan water for 40 days showed several tiny corrosion spots on the inside surface. No change was noted after 101 days or after 7.4 months. The corrosion at the unprotected ends where the pipe was cut was about the same as on the uncoated specimen.



(a) (b) (c)

Fig. 11. Uncoated Pipe in Raw Lake Michigan Water

Key: (a) after 40 days; (b) after 101 days; (c) after 7.4 months.

Chlorinated-Water Specimens

The water was chlorinated from the beginning of the test, Aug. 24, 1952, until Jan. 14, 1953, with the application of an average dose of 1.9 ppm, yielding an average chlorine residual between 0.5 and 0.7 ppm. After 40 days there were approximately 20 small tubercles on the outside of the pipe and approximately 75 fairly large tubercles on the inside, with about the same number of tiny rust spots. The tubercles ranged in size up to approximately ½ in. in diameter. The velocity of the water where this pipe was suspended was greater than at other locations. The tubercles were slightly elongated and were beginning to form a crust.

After 101 days the specimens seemed to show increased activity. The pinpoint tubercles had become larger and were hard on one side and elongated in the direction of the flow of water.

After 7.4 months, the largest tubercles were ¾ in. in diameter. The first estimate of 75 fairly large tubercles appeared to have been excessive. Not more than 50 of the larger tubercles were present. Somewhat greater corrosion than in water with no treatment was to be expected, as the chlorination was equivalent to adding 2 ppm of hydrochloric acid to the water.

Filtered-Water Specimens

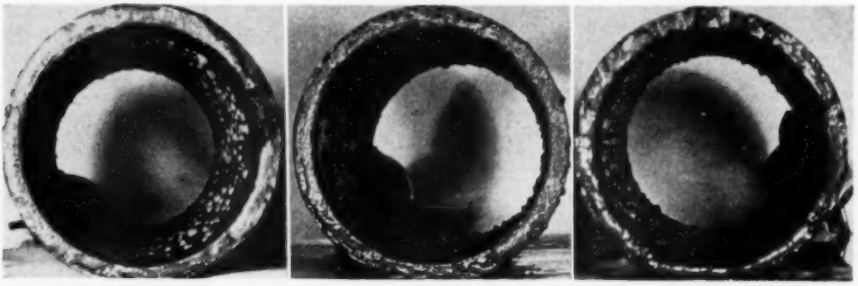
Three specimens of coal-tar coated pipe were suspended in the two filtered-

water reservoirs. All showed a few small tubercles and numerous tiny corrosion spots on the inside after 40 days, with very little change noted in succeeding examinations.

Three specimens of uncoated cast-iron pipe were suspended in the north filtered-water reservoir and two in the south reservoir. The water in both reservoirs received about the same treatment, except for the period from Feb. 5 to Mar. 29, 1953, when ammonium sulfate was added after filtration to the water in the south reservoir. The pH of the water was maintained near 8.1 in both reservoirs.

there was no further increase in size.

After 40 days a specimen in the south reservoir showed 24 tubercles on the outside of the pipe. On the inside, the condition resembled that of the north reservoir specimen described, except that some tubercles were larger and there was a greater number of the pinpoint variety. After 101 days the tubercles had increased in size somewhat, with some of the larger ones becoming more firm to the touch. The pinpoint rust spots had also grown and almost completely covered the surface. There appeared to be no change after



(a) (b) (c)

Fig. 12. Uncoated Pipe in Chlorinated and Filtered Water

Key: (a) after 40 days; (b) after 101 days; (c) after 7.4 months.

Figure 12a shows one of the specimens in the north reservoir after 40 days. Numerous active tubercles, $\frac{1}{8}$–$\frac{1}{2}$ in. in diameter, were present on the outside of the pipe, while the inside was covered almost entirely with 300–400 rust spots or tubercles $\frac{1}{8}$–$\frac{1}{4}$ in. in diameter. The rust spots generally are not called tubercles until a hard crust forms over the soft precipitate of ferric hydroxide. After 101 days (Fig. 12b) some of the tubercles appeared larger. By 7.4 months (Fig. 12c) a thin crust had formed over most of them and 7.4 months, but the tubercles were a little harder.

Interpretation

The tests were of such short duration that the results represent only the initial stages of corrosion. As soon as water comes in contact with uncoated cast-iron pipe, corrosion starts through the formation of anodic areas over the surface. Since an iron oxide film covers the surface, the anodic areas apparently start where holes exist in the film. Examination of the corrosion at

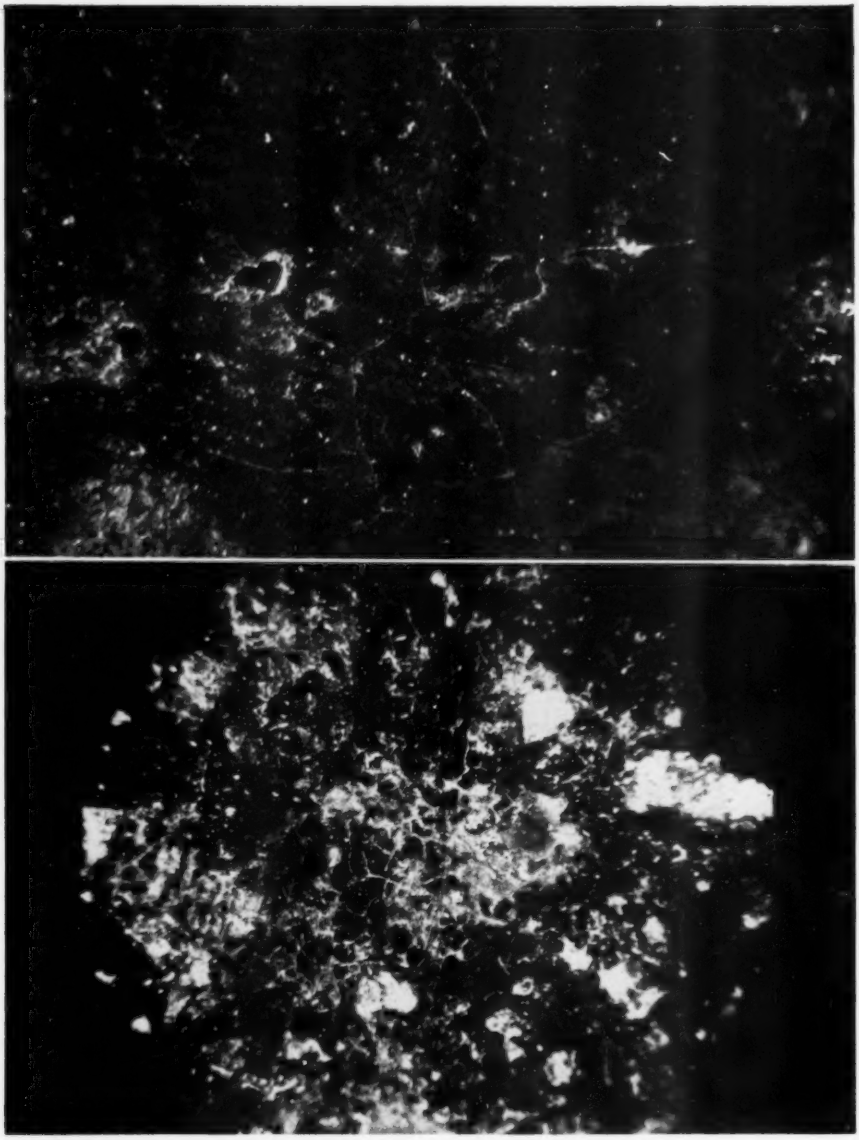


Fig. 13. Crazing in Coal-Tar Coating

Top—typical crazing in coating on Chicago pipe; bottom—crazing in pipe from an eastern city with relatively corrosive water.

the ends of the pieces of pipe where the cuts were made shows the surface almost completely covered with rust.

Probably within a day or less, the pattern of corrosion has been set; that is, whether a tubercle of pinpoint size or one considerably larger will develop. Presumably the character of the water in contact with the pipe, within the quality range suitable for a public supply, has little influence on corrosion during the first day of contact, or, possibly, even during the first few weeks. Early students were mispuzzling that so few tubercles form on the outside of the pipe compared with the number on the inside.

Cracks in Coating

The photograph at the top of Fig. 13 is a typical example of crazing in the coal-tar coating of a piece of pipe. Along the line of crazing were a few small tubercles which became dislodged when the pieces were washed. Although all corrosion does not take place along the cracks, it is more prevalent in such places. The lower portion of

Fig. 14. Pieces of Stone in Pipe

This 30-in. main was laid in 1922. Most of the stones were spherical in shape, with a diameter of 1–1½ in., but some were considerably larger.

led by this fact and thought there was no need to treat the water to lessen corrosion.

The formation of dome-shaped rust spots proceeds rapidly to the size they will take in the first stage of corrosion, whether the dome is as small as $\frac{1}{16}$ or as large as $\frac{3}{4}$ in. in diameter. The dome stops growing as soon as the crust or hard membrane starts to form, except for the spicule type of tubercle, in which the hard membrane keeps extending out from pipe surfaces in the form of a cylinder with a diameter likewise varying from $\frac{1}{16}$ to $\frac{3}{4}$ in. It is

Fig. 13 shows crazing in a pipe section obtained from an eastern city. The water was believed to be more corrosive than Chicago's, for the piping was badly tuberculated.

Condition of Chicago Piping

Compared with some other cities, the condition of the piping in Chicago would be called excellent. This does not mean there is no corrosion, however. Because an elaborate system of corrosion tests seemed too costly, it was decided to study the condition of the

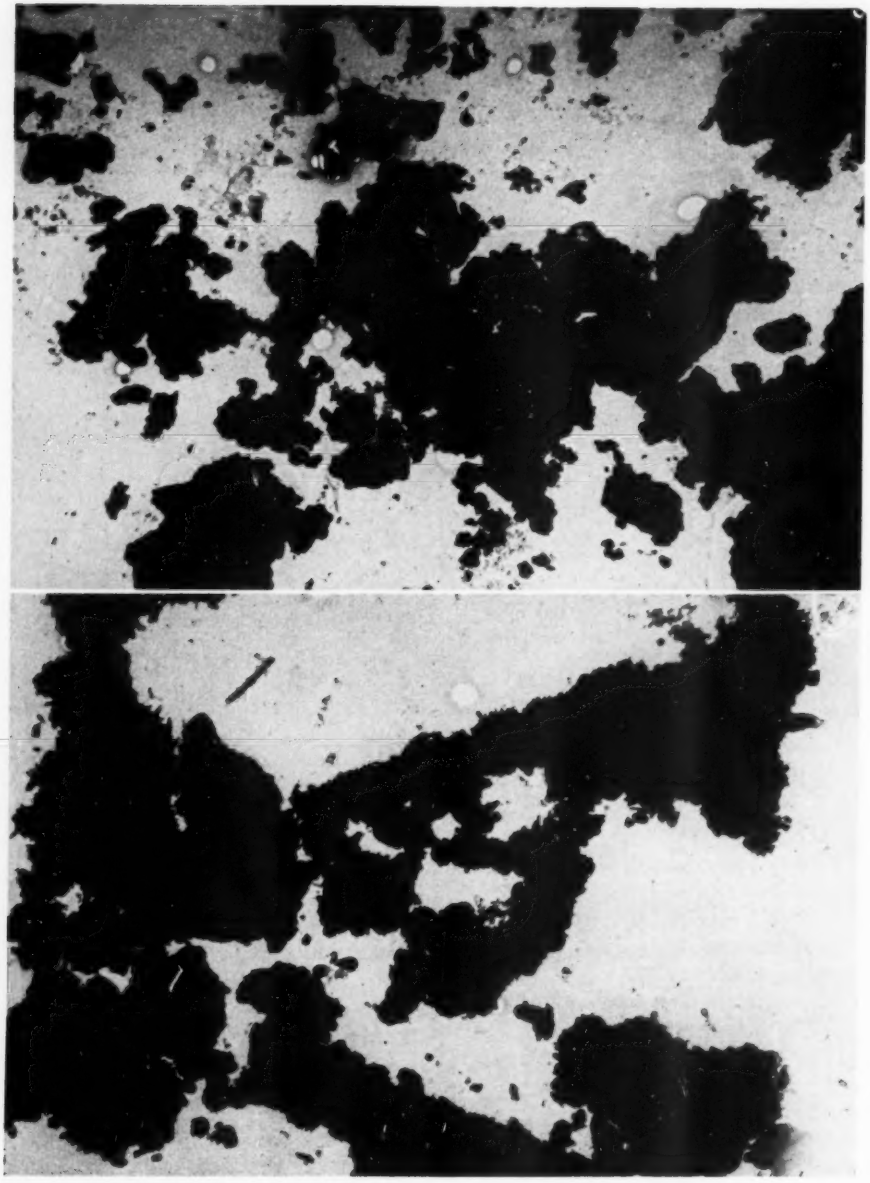


Fig. 15. Electron Photomicrographs of Tubercles

Top—dormant tubercle; bottom—active tubercle.

cast-iron water mains throughout the city and conduct limited tests at the South Dist. Filtration Plant. Improvements in the water distribution system have made it necessary to take out pieces or full lengths of pipe at various places. It has therefore been possible to examine the inside surface of a number of large mains at a variety of places.

These observations, made in 1952 and early 1953, are in addition to those previously described, which were largely on cutout pieces. The absence of rust tubercles on the inside surface of the cutout did not necessarily mean that none would be found in a full length of the same pipe. The condition of the coal-tar coating on the cutout, however, was probably the same as on the full length. If a few tubercles were found in the specimen, it is likely that there were many in the pipe.

The work in 1952–53 was confined chiefly to the examination of large-size pipe from which a 12-ft length, or portion of it, was removed from the ground. In two instances, several lengths were removed from a block of pipe. The pipe from the central water district should demonstrate the condition of the mains in contact with chlorinated raw Lake Michigan water. It is believed that the condition of the piping system in the south water district was the same as in the central district before chemical treatment of the water was started in 1945.

Unfiltered-Water Area

In some piping laid in 1923, the coal-tar coating on the inside was found to be soft and blistered, with most of it washed away in a strip 6–12 in. wide at the bottom of the pipe. On each side of this strip, over a width of a few inches to a foot or more, there were numerous tubercles. In only a few lengths of pipe were there many tubercles over most of the surface.

The tubercles were cone shaped, with the apex at the upstream end. Practically all of the tubercles had been dormant for a number of years. The few active ones are believed to have become so after the line had been taken out of service and before it was removed from the ground.

Inspection was made of a 10-ft length of 30-in. cast-iron main laid in 1922. The pipe, as it lay in the ground, was covered with sediment approximately 3 in. thick at the bottom. Mixed with the sediment was a large amount of crushed stone, gravel, and a few other items, such as parts of glass bottles. Some of the pieces of stone measured approximately 5 in. in length, 4 in. in width, and 1½–2 in. in thickness. The vast majority of them, however, were spherical, with a diameter of approximately 1–1½ in.

The inside mud and most of the gravel was washed out with a fire hose before photographing (Fig. 14). The coal-tar coating was blistered and cone-shaped tubercles were present, nearly all of them confined to the lower part of the pipe. Most of the tubercles had undoubtedly formed a number of years ago, and very few were active. Figure 15 is an electron photomicrograph of the inside of two tubercles, the top dormant and the bottom active. No bacteria were found in any of the tubercles examined with the electron microscope.

Figure 16 (top) shows a length of 100-year-old 10-in. main still in service. Behind it is a new 24-in. pipe. The old pipe contains two tapping rings, faintly visible in the photograph. These provided thicker sections where service

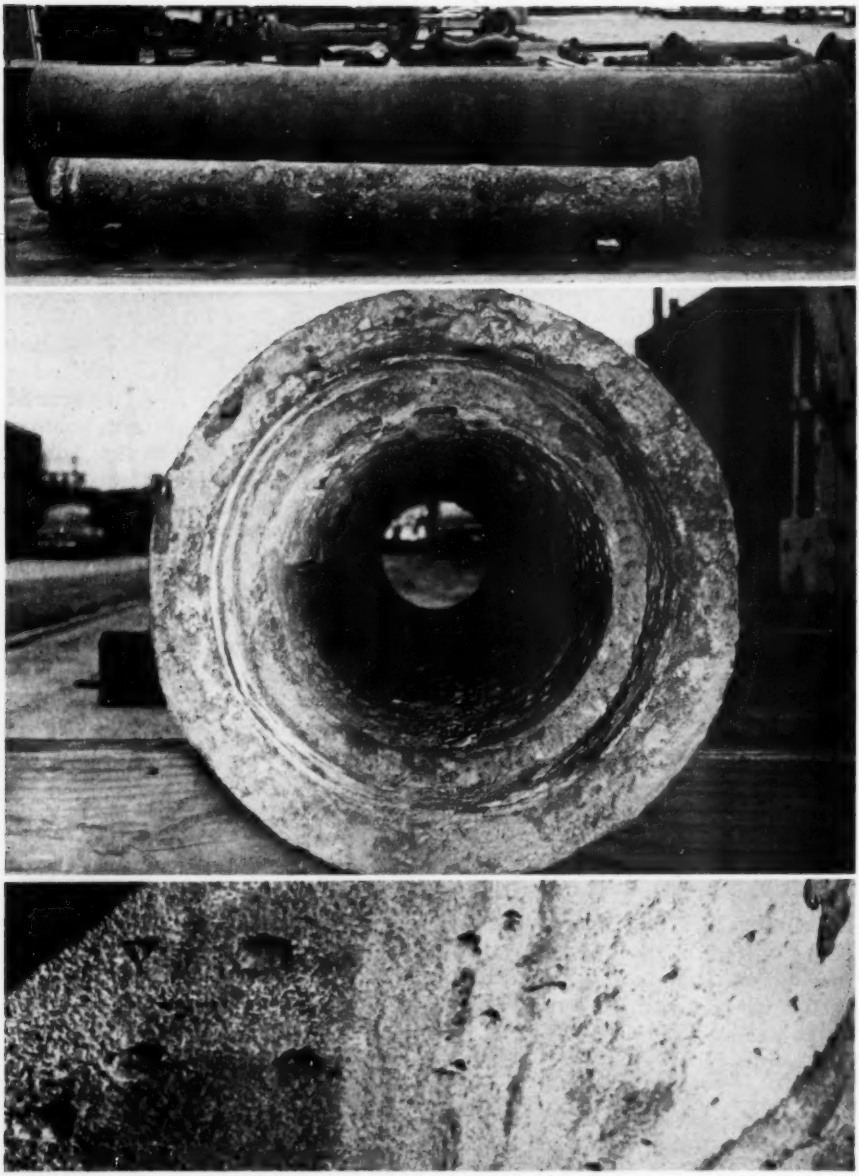


Fig. 16. Century-old Main Still in Service

Top—length of old 10-in. pipe next to new 24-in. main; center—inside of pipe; bottom —closeup of tubercles.

taps were to be made. There was some corrosion on the outside of the pipe but very little penetration.

The middle portion of Fig. 16 shows the inside of the old pipe at the bell end. The photograph indicates considerable iron rust along the bottom of the pipe, which was actually the top while in service. The apparent tubercles at the bottom are actually sediment and loose material, although a few real tubercles may be noticed along the sides. The tuberculation was not great and the pipe could still be considered in good condition on the inside. Figure 16 (bottom) is a close-up of several of the tubercles. It also shows the sand mold surface of the pipe, which has resisted corrosion throughout the years. A very thin coating of calcium carbonate covered the pipe surface.

The tubercles had been dormant for many years, and there was no evidence of recent corrosion. Left in service, the pipe probably would be in the same condition 50 or 100 years from now, unless a change in the character of the water disturbed the present stable condition of the pipe.

Fig. 17. Corrosion in 67-year-old Pipe

The pipe carried unfiltered water. The many tubercles are of two types: cone shaped and irregular.

Fig. 18. Long, Cone-shaped Tubercles

The length of the tubercles—up to 3–4 in.—indicates a relatively rapid flow of water.

An 8-ft length of 24-in. pipe, cut from a water main laid about 1885, contained more tubercles than any other Chicago specimen examined. All of them had been inactive for many years. Figure 17 shows the tubercles on the inside of the pipe, many of them cone shaped. There are a number of larger tubercles of irregular shape, however,

similar to the ordinary type found in many water pipes. The piece of pipe is shown in approximately the same position as when it was in the ground. The condition of the outside of the pipe was almost perfect and no corrosion was noticed.

A 14-ft length of 36-in. pipe laid in 1898 was in very good condition, with only a small number of cone-shaped tubercles, except in a few places. These were not uniform over the entire surface. Figure 18 shows an area where the cone-shaped tubercles were more numerous than the average. The tubercles were longer than those found in many pipes, indicating that the water flow had been fairly rapid. With rapid flow, the tubercles do not have a chance to build up a cone characteristic of pipe with lower flow velocities. Some of the tubercles were 3–4 in. in length.

A layer of mud at the bottom of the pipe, approximately 18 in. wide, was washed out before the photograph was made. More tubercles existed along the bottom line than at other parts of the inside surface, a characteristic condition of corrosion in other large pipes. The coal-tar coating was soft, brittle, and slightly blistered. The outside of the pipe was in excellent condition.

Fig. 19. Badly Tuberculated Pipe

This 36-in. pipe was laid in 1898. The coating was blistered in some places.

A very badly tuberculated 36-in. pipe, laid in 1898, is shown in Fig. 19. The coal-tar coating was blistered in some places.

Filtered-Water Area

All evidence leads to the assumption that the corrosion in the south water district was of the same nature as that in the central district up until the time the South Dist. Filtration Plant was placed in operation. During the period

in which the water was coagulated and settled, but not filtered, a slime coating of aluminum hydroxide formed over the surface of the pipes. This formation may have been aided by the use of acid-treated sodium silicate at intervals, before the filters were placed in service. The more acid water caused corrosion to begin to increase in the south district water mains.

Some of the new tubercles continued to be active until a split treatment of aluminum sulfate and ferrous sulfate and lime was started in April 1952. Active tubercles are not now found in piping of the south district, indicating that the new treatment has almost completely stopped the corrosion.

A 24-in. pipe laid in 1907 exhibited a line of tubercles along the bottom, as

Fig. 20. Ridged Gelatinous Coating

The absence of ridging to the left of (downstream from) the large tubercle in the lower left quadrant may be noted.

The gelatinous coating covered all of the old tubercles and probably most of the new ones. The coating, however, was not entirely effective in stopping corrosion, so that, after it had formed, there was some increase of tuberculation in the piping of this district. The evidence indicates that the number of tubercles increased 15–20 per cent. well as a few elsewhere on the inside. This pipe section reveals much of what has taken place since the beginning of the chemical treatment of the water at the South Dist. Filtration Plant. Figure 20 is a good illustration of the gelatinous ridging. As the film was very soft, it is difficult to explain how it formed in this shape and to under-

stand why it has not been washed away after several years. In the lower left quadrant of the photograph is a tubercle which had formed and become dormant before the chemical treatment of the water was started. It acted as an obstruction to the flow of water, and it is interesting to note that no ridging was produced downstream (direction of water flow was right to left) from the tubercle for a distance of approximately 1 in., with at least 2 in. required for the ridges to become of normal size.

The old tubercles, while dark in appearance, were covered with the white gelatinous coating. The smaller tubercles in the left half of the photograph also show no ridging on the downstream side. Tubercles that formed after the coating had been deposited are of darker appearance (red) and were not coated with the film. These tubercles have had no effect on the ridging and are now dormant. The disturbance they make in the flow of water is not enough to wash away the gelatinous ridges.

Two of the newly formed tubercles are shown in the upper left quadrant of the photograph and one in the lower left. A number of them were distributed throughout the pipe section. These tubercles indicate that once the ridged coating had formed, there was no further tendency for the process to continue. Consequently, it can be concluded that practically all of the film formation on the inside of the pipes

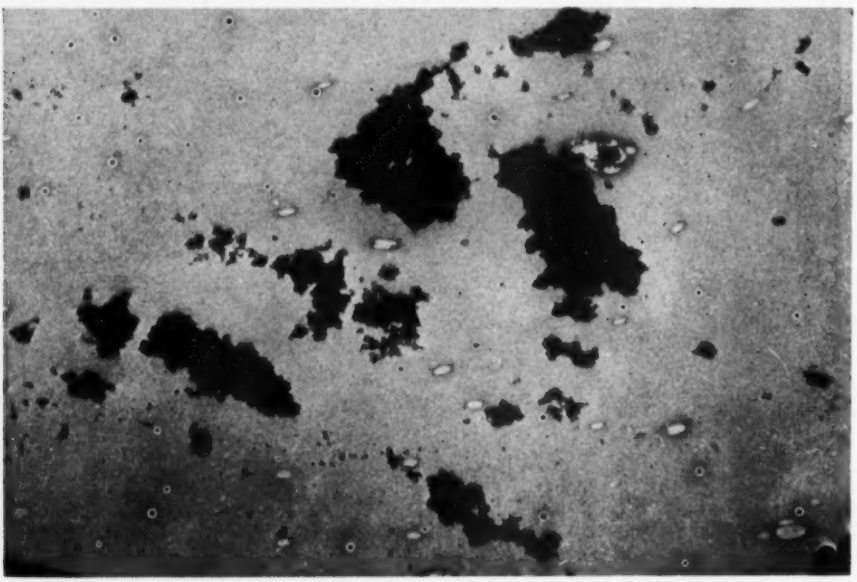


Fig. 21. Electron Photomicrograph of Gelatinous Coating

The coagulated matter appears to be more firmly compacted than when freshly formed.

occurred before the filters were placed in service. There was very little ridging along the bottom of the pipe. If ridging of the coating did take place in this part, most of it has been washed away, indicating that within the course of time the gelatinous film will largely disappear.

when freshly formed. Shells of diatoms were noticed in the precipitate, indicating that it came from waters coagulated prior to filtration.

Two lengths of a 48-in. pipe laid in 1911 were examined. The pipe evidently carried water at low velocity most of the time, as there was approxi-

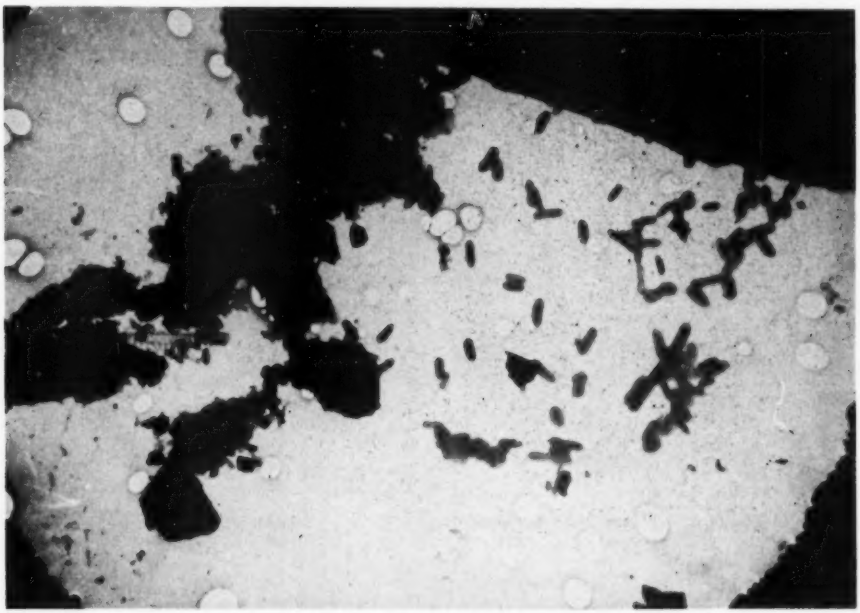


Fig. 22. Electron Photomicrograph of Sediment in Pipe

The pipe had been dewatered several days before examination, and most of the bacterial growth may have developed in the interim.

It has been known for some time that the flow of water along a solid surface is not uniform but it would have been difficult to conceive that so soft a material as aluminum hydroxide would form ridges at right angles to the flow. An electron photomicrograph of the gelatinous coating (Fig. 21) shows nothing unusual, except that the coagulated matter is compacted more firmly than

mately 7 in. of sediment at the bottom. This assumption was corroborated by the appearance of a few tubercles that had been active after the slime coating had been deposited in the pipe. These were of the spicule type and pointed straight outward, indicating that the flow of water was not very great. All of the tubercles seemed to be dormant at the time of the examination.

A sample of sediment from the bottom of the pipe showed bacteria under the electron microscope (Fig. 22). The pipe had been dewatered several days before examination, and most of the bacterial growth may have developed in the interim.

A 16-ft section of 48-in. piping laid in 1911 contained a large number of tubercles along the bottom and, in some places, along the sides. Most of the tubercles were cone shaped and pointed downstream. No active tubercles were found. Most of them were small and some had formed after the deposit of gelatinous coating.

The piping in many water systems has been found covered with a white gelatinous coating. In one other city, the coating was found ridged, as in Chicago. Analysis of the coating has shown it to consist mainly of aluminum hydroxide, with considerable silica. It is not composed of calcium carbonate, except in cities where the water is softened.

Corrosion in Other Cities

Some information on corrosion in a few other cities has been obtained by the author within the past two years, in addition to data acquired during more than 30 years of intermittent study of the subject. The recent information comes chiefly from Great Lakes cities in which the water without chemical treatment is saturated, or almost saturated, with calcium carbonate and is not very corrosive to piping with coal-tar or galvanized coatings. Chemical treatment and filtration in most of these cities has caused the water to become more corrosive than it was before the treatment. Low turbidity, requir-

Fig. 23. Effect of Moderately Corrosive Water

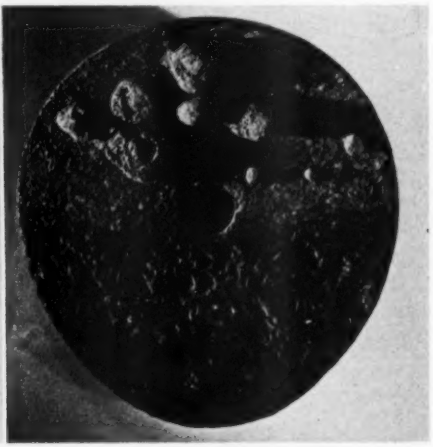


Fig. 24. Tubercles Removed From Half of Area

A pipe section from a city using water more corrosive than that of the Great Lakes is shown in Fig. 23. In Fig. 24, the tubercles have been partially removed, and some of the corroded areas have been cut out with a knife.

ing low coagulant dosages, has made the corrosion problem less difficult than in cities where the water is more acid.

Many take the attitude that the corrosion produced by Great Lakes water, and waters of similar chemical balance, is so slight that there is no need to consider its effect. Within the course of years this attitude will be found to be a mistake. Pipe cleaning already has been resorted to for a few mains in several cities obtaining water from the Great Lakes. If the pipes can be relined effectively after cleaning, it may be all right to do so. Although cleaning without relining may give relief for a few months, it exposes many new areas of the metal surface where corrosion will become more intensive after the cleaning than it was before.

As a result of these examinations, the author believes that 50 years of water treatment will see the water mains in much worse condition than 50 years of exposure to the lake water without chemical treatment.

One example of corrosion in a city using water more corrosive than Great Lakes water is shown in Fig. 23. This 8-in. cutout on a 10-in. main shows several tubercles. The tubercles were removed from half the piece, and the soft areas in the cast iron were partly cut out with a pocketknife. This procedure did not remove all of the corrosion, which had penetrated the metal $\frac{3}{16}$–$\frac{1}{4}$ in. over a considerable portion of the cleaned area (Fig. 24). (The corroded depressions do not show up well in the photograph and may appear to be mounds.) If this tuberculated condition is general over the pipe surface, corrosion already has seriously weakened the strength of the pipe, in addition to increasing the friction loss through tuberculation.

The membrane over the tubercles has not formed as hard a crust as in less corrosive water. This is a most significant fact, for much depends on the imperviousness of the membrane and its consequent ability to stop corrosion. Membranes that stop corrosion entirely apparently can be formed only in water at or close to the saturation equilibrium of calcium carbonate. An iron pipe with no coating will, however, corrode to a considerable extent in water saturated with this compound. The initial corrosion rate for an unprotected iron surface is too great for corrosion to be stopped immediately, as was shown by the previously described tests on uncoated pipe in the lake water. On the other hand, water capable of arresting corrosion in uncoated pipe would deposit material on the pipe wall so rapidly that it might cause as much trouble as the tuberculation.

Even though cities may be centuries old, iron pipe distribution systems are comparatively recent. Not many cities have cast-iron piping that has been in service more than 100 years. The engineer has done a wonderful job in constructing water systems, but he has not done much to develop everlasting carriers of water through the streets and into buildings. The best coal-tar coating is soon full of holes, sometimes before the pipe is placed in the ground. The quality of coal-tar linings appears to deteriorate over the years, and some of it becomes so poor that the metal underneath begins to corrode as soon as it comes in contact with water. A noncorroding pipe at a cost that is reasonable enough for practical use may some day be developed, but it does not exist today. Even if a noncorrosive pipe were available, water works operators would be confronted with the fact that

there is an enormous value of piping in use which is protected only by coal-tar and galvanized coatings.

Aluminum hydroxide coatings similar to those on Chicago pipes have been found in other water systems (Fig. 25). The coating is giving considerable protection, but it, too, is full of holes and will allow some corrosion to develop.

Effect of Chlorine

The effect of chlorine on corrosion is being studied. If it did nothing more than increase the acidity of the water, it would have some effect, though little compared with other influences. In waters of low dissolved-oxygen content, residual chlorine may help oxidize the products of corrosion. It is known that water free of dissolved oxygen will not tuberculate.

The effect of residual chlorine on coal-tar coatings is not known. There is the possibility that it hastens disintegration of the coal-tar surface, but the author has observed such disintegration where no chlorine had been used. Chlorine is believed to cause little corrosion in most waters. It is certainly not the major cause.

One water chemist believes that the use of ammonia in water would prevent corrosion. If he is correct, this would be of importance. It is believed however, that the most that could be expected would be a lessening of corrosion to some extent. Residual chlorine cannot penetrate tubercles or iron rust precipitates. If it could, it might be helpful in sealing tubercles and decreasing the corrosion.

The corrosive effect of chlorine should be given more attention. The principle of maintaining residual chlorine throughout the distribution system as a health measure most likely is here to stay, as is high prechlorination in some waters. If it can be shown that ammonia will lessen corrosion, it may be economical to use it. Chicago is conducting experiments along this line at present.

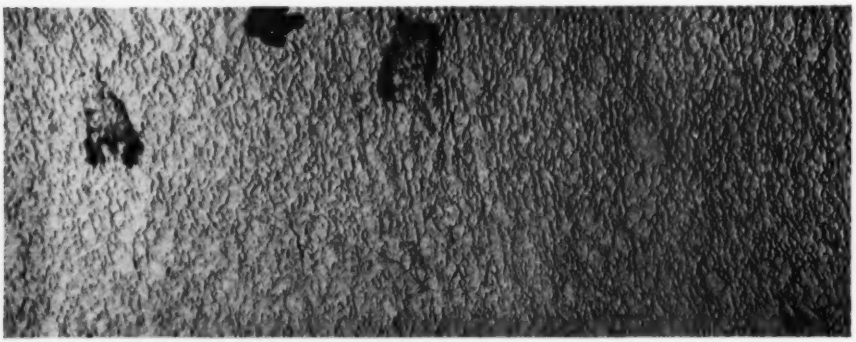


Fig. 25. Aluminum Hydroxide Coating

This coating, which is of the type found on pipes at Chicago, is giving considerable protection to a 45-year-old main still in service at another city.

Effect of Velocity

That velocity has great influence on tuberculation does not seem to have been given much consideration. Cer-

tainly, a spicule tubercle projecting straight out from the pipe wall will offer more resistance to the flow of water than would a spicule of the same area lying flat on the surface of the pipe in the line of flow, as shown in Fig. 18.

A 60 × 45-in. iron venturi tube was used to study the effect of velocity on corrosion. The tube had two brass rings molded into the iron, and the inside surface of the iron and brass was later made smooth. The average velocity of the water through the main section of the meter tube was approximately 8.7 fps and 15.5 fps through the throat section.

In the machined part of the cast iron on each side of the 60-in. brass ring, numerous cone-shaped tubercles, 1–3 in. in length, were formed. Their shape was somewhat like the right-hand illustration in Fig. 2b. Between the two rings, the tubercles were longer and lay closer to the metal surface—more so than in the left-hand illustration of Fig. 2b. No tubercles occurred on the cast iron on either side of the 45-in. brass ring, even though the coal tar had been washed away. Beyond the ring, at the beginning of the recovery section, a few very slender tubercles, $\frac{1}{16}$–$\frac{1}{8}$ in. in diameter, were present. They were 1–2 in. in length and were lying so flat on the surface that they were not readily noticeable.

An average velocity of 15.5 fps prevented tuberculation, even with a fresh metal surface exposed to the water, whereas half this average velocity did allow tubercle formation.

Need for Research

The brains of the best water chemists will be required to develop practical water treatment methods to aid as much as possible in decreasing the great loss now being caused by corrosion. The sooner they get to work on the problem, the sooner the cost of corrosion will be lowered. The author hopes that the present article will serve to stimulate interest in the subject.

Acknowledgment

The investigation of corrosion at Chicago is being conducted by the Dept. of Water and Sewers. Nearly all of the camera photographs were made by William Meeks, a laboratory worker. The electron photomicrographs were made by L. I. Scarce, Biologist.

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Revised Main Disinfection Procedure

By Marshall P. Crabill

A contribution to the Journal by Marshall P. Crabill, Chairman, Committee E7.D2—Procedure for Disinfecting Water Mains; Supt. of Purif., Indianapolis Water Co., Indianapolis, Ind.

THE Committee on Main Disinfection, in revising the procedural document (see p. 835, this issue) has endeavored to make it both practical and workable. The first consideration in this or any other procedure or specification is to weigh the need for it. No one will deny the need for the disinfection of newly laid mains, or repaired old ones, where the samples of the water delivered fail to meet public health standards. That is the one and only basis of the need for disinfection. Other conditions, such as tastes or odors, may require treatment, perhaps chlorination, but not for the purpose of disinfection. The committee presents the most practical method known at present to assist in furnishing a water that will meet public health requirements.

It is recognized that sometimes, or perhaps often, a newly laid main may not require more than flushing. It is not unreasonable to acknowledge that, under certain conditions of treatment, some waters materially reduce the possibility of aftergrowth in the distribution system. Neither is it unreasonable to acknowledge that some newly laid pipelines are handled a great deal more carefully and with greater regard for cleanliness than others. Some types of lining and some methods of joining pipe lengths tend to improve the possibilities of recovering satisfactory samples. Extreme care and cleanliness cannot, however, be accepted as prima facie evidence that disinfection is not needed. That evidence can be gathered only on the basis of actual sampling with satisfactory results determined in the laboratory. Exception to the need for disinfection is recognized in Sec. 7 of the procedure.

Many water utilities are not equipped with laboratory facilities to determine whether or not the samples from the mains meet public health standards. Under these conditions, the committee feels that the decision on the need, or the lack of need, for disinfection should be made by the public health authority having jurisdiction in the area of the utility. The decision can be made either on the basis of sample results submitted to the authority by the utility, or on samples collected and tested by the health authority. Sampling should be done with full regard to proper standing time in the new main, and a single sampling should not be considered complete evidence.

The revised procedure leaves the decision on the need for swabbing a new pipe to the person directing the main-laying program. It seems obvious that some pipe will require swabbing with a disinfecting solution and that some will not. One has only to look at the pipe

interior before it is lowered into the trench to determine whether or not flushing is likely to remove the incrusted matter. If not, there is a definite need for swabbing. Plainly, the only person who is qualified to make that decision is the person on the job. The committee feels that, if inspections are made in a conscientious and workmanlike manner, swabbing will be done when and if it is essential.

For any job other than an unusual one, the magnitude of chlorine application and chlorine residual remaining after the recommended contact time has been reduced in the revised procedure. This reduction has the advantage of permitting the use of smaller-capacity equipment, which, for many utilities, may mean that existing equipment will serve satisfactorily. It also permits more rapid bleeding of diluting water into the new main, which tends to reduce the overall time required to apply the disinfectant. The size of the chlorine application was not decreased without trial, and the results on jobs where lower applications were used equaled those with higher applications.

In World War II, the British adopted a much lower residual than the earlier AWWA procedure as being more practical and equally as efficient in meeting the demands of adequate disinfection. No evidence is reported that the lower applications were not satisfactory.

The revised procedure departs from the original in implying the use of only such packing material as is approved in the Specifications for Installation of Cast-Iron Water Mains—AWWA C600. This establishes a uniformity between two documents that are in fact closely associated. No method for treating unapproved packing materials is given. All of the methods studied in the past produce variable results and cannot be defended.

To be effective in removing the lighter solid particles, the velocity of the flushing water must be sufficient to pick up and transport these particles to the discharge point. The committee attaches considerable importance to maintaining a velocity of not less than 2.5 fps through the main being flushed. This should not be assumed to be a scouring velocity and should not be used as an excuse to avoid swabbing heavy incrusted matter. If there is heavy material in the main, swabbing is essential and no advantage will result from avoiding it. Flushing can be depended upon to remove only the lighter solids, even if the recommended velocity is maintained.

The procedural document emphasizes that bacteriological quality cannot be judged from samples collected from hydrants. This warning should not be ignored. In many disinfection jobs, coliform organisms have been found in all samples collected at a hydrant, although totally absent in samples taken 50 ft away through a riser pipe installed on a corporation cock. The riser pipe, if it was not installed at a time when it could be filled with disinfectant solution from the main, was, of course, disinfected separately.

The only disinfecting agent recognized in the procedure is chlorine in one of several forms. This does not preclude the use of another disinfecting agent if it has been tried and is approved by the local health authorities. Several disinfectants other than chlorine have been found entirely satisfactory, particularly in the swabbing operation. The committee could not, however, undertake to test all the other disinfectants.

Indianapolis Experience

The author's utility was recently faced with an unusually difficult disinfection problem. A main approximately 34,000 ft long had to be laid from the pumping station to the site of a large plant manufacturing electrical equipment. A creek crossing was involved, and the main was contaminated with trench water on several occasions during the laying. The plant had its own laboratory for making routine bacteriological determinations on the water, for industrial and drinking use, which was to be delivered from the main to various parts of the plant by a small, plant-owned distribution system.

The situation demanded full utilization of all available knowledge to make the disinfection really successful. Fortunately, mechanical-joint pipe was employed. The main was chlorinated in sections, as completed, and then water with high chlorine residuals was flushed through every hydrant in the line. It was necessary to rechlorinate the creek crossing and adjacent sections before satisfactory samples could be recovered. In no instance was a satisfactory sample collected from a hydrant, although special sampling risers nearby produced good results. The piping at a new automatic booster station in the utility's system also had to be chlorinated. The last section of main was chlorinated within a few days after the laying had been completed, and satisfactory samples were obtained throughout the entire line. Following the utility's example, the manufacturing plant decided to disinfect its own distribution system. The utility did not take part in this phase of the work except to offer advice and check the bacteriological results. The disinfection of the intraplant system was accomplished rapidly and successfully.

It is, of course, impossible to estimate how much illness or discomfort was avoided through disinfection of the mains, but it is gratifying to the utility to know that it is furnishing this industry, and all other consumers, with a water meeting public health standards. Thus, the utility is discharging its obligation to employ every available means in providing a safe and palatable water.

Conclusion

There is still much to be learned about main disinfection. The committee does not believe that the revised procedure will remain in its present form indefinitely. If it does, this fact will indicate that it is being disregarded, as it can be improved only through constructive criticism based on the experience gained by water works men using the procedure. There is substantial evidence, however, that the revised procedure is workable, and, at present, no evidence exists that it will not produce satisfactory results.

AWWA C601-53T
(*Formerly* 7D.2)

American Water Works Association

A Tentative Procedure

for

DISINFECTING WATER MAINS

This "Procedure for Disinfecting Water Mains" is based upon competent experience and is intended for use under normal conditions. The procedure is not intended for unqualified use under all conditions.

Approved as Revised by AWWA Mar. 6, 1953

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"A Procedure for Disinfecting Water Mains" was originally adopted by AWWA on Sept. 30, 1947, and published in the February 1948 Journal. A minor revision was made on Sept. 15, 1948. The present text represents a complete revision of the entire procedure and was approved by the AWWA Board of Directors on Mar. 6, 1953.

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Foreword

It is the intent of this document to present a practical and workable main disinfection procedure suitable for application under any reasonably normal conditions. Published records show that no procedure for the disinfection of newly laid water mains has been universally or continuously satisfactory. In the water in newly laid mains, types of bacteria that are indicative of pollution may be found. Since laboratory tests cannot determine their origin, it is necessary to take all possible precautions to keep them out, or to destroy them where tests show them to be present.

The revised procedure in no way reduces the water quality requirements before the main can be placed in service. In all instances, the quality must be proved by satisfactory samples.

Users of this procedure are cautioned that there is a need for thorough displacement of strong disinfectant solutions from the mains and for keeping such solutions from entering service lines. Illness or discomfort and damage to household plumbing or fixtures may result from the use of water containing strong disinfectants.

Some metals may be damaged by these solutions. It is solely the responsibility of the person acquainted with the local conditions to recognize and guard against these hazards.

No procedure for disinfection of jute is included, because jute is not listed as acceptable in the Specifications for Installation of Cast-Iron Water Mains—AWWA C600.

It may be found advantageous to combine the disinfection of a newly laid pipeline with the hydrostatic tests required under Sec. 13 of AWWA C600. The decision concerning the combining of such operations is, of course, the prerogative of the engineer in charge of the installation of the new main. Combining disinfection and the hydrostatic test may, however, sacrifice the advantage of an initial flushing out of the lighter solids and particulate matter having a chlorine demand. Repetition of the disinfection procedure may be required, resulting in an overall delay.

The development of this procedural document by the Association implies the responsibility of the water works executive for all steps in the disinfection procedure, including the sampling and laboratory examination of water from the main after disinfection has been completed. It is assumed that the health authorities, at either the local or state (provincial) level, maintain a cooperative interest in the operations. If the water works executive desires to relinquish to the health authorities his responsibility for sampling and laboratory examination of water from the disinfected mains, there is no reason why he should not do so.

A Tentative Procedure for

Disinfecting Water Mains

Sec. 1—Pipe Kept Clean

The interior of all pipe, fittings, and other accessories shall be kept as free as possible from dirt and foreign matter at all times.

Sec. 2—Pipe to Be Cleaned and Treated

When the pipe is laid, it shall be as free as possible of all foreign matter. If, in the opinion of the engineer or job superintendent, the pipe contains dirt that will not be removed during the flushing operation, the interior of the pipe shall be cleaned and swabbed, as necessary, with a bactericidal solution.

Solutions for swabbing may be made from the compounds listed in Sec. 10.1. No other compound shall be used unless it is approved by the local and state health authorities.

Sec. 3—Laying Pipe

Every precaution shall be used to protect the pipe against the entrance of foreign material before the pipe is placed in the new line. At the close of the day's work, or whenever the workmen are absent from the job, the end of the last laid section of pipe shall be plugged, capped, or otherwise tightly closed to prevent the entry of foreign material of any nature.

If the contractor, or pipe-laying crew, cannot put the pipe into the trench, and in place, without getting earth into it, the engineer may require that, before lowering the pipe into the trench, a heavy, tightly woven canvas bag of suitable size shall be placed over each end and left there until the connection is to be made to the adjacent pipe.

Sec. 4—Preventing Trench Water From Entering Pipe

At times when pipe laying is not in progress, the open ends of pipe shall be closed by a watertight plug or other means approved by the engineer. Joints of pipe in the trench shall be poured before the work is stopped. If water is in the trench, the seal shall remain in place until the trench is pumped dry.

Sec. 5—Packing Material

This procedure implies the use of only such packing material as is included in the list of acceptable materials in the Specifications for Installation of Cast-Iron Water Mains—AWWA C600. Packing material shall be handled in a manner to avoid contamination and shall be dry when placed in the joint. All such material shall be free of oil, tar, or greasy substances.

Sec. 6—Flushing Completed Pipelines

6.1. *Preliminary flushing.* The main shall be flushed, prior to chlorination, as thoroughly as possible with the water pressure and outlets available. Flushing shall be done after the pressure test has been made. It must be

understood that flushing removes only the lighter solids and cannot be relied upon to remove heavy material allowed to get into the main during laying (see Sec. 2). If no hydrant is installed at the end of the main, a tap should be provided large enough to develop a velocity in the main of at least 2.5 fps (see Table 1 for openings required to flush pipelines at a 2.5-fps velocity).

NOTE: It will be found difficult to flush mains over 16 in. in diameter at the 2.5-fps rate. In such instances, the requirements of Sec. 2, 3, and 4 must be rigidly enforced.

6.2. *Valve damage by foreign material.* Unless proper care and thorough inspection are practiced during the laying of water mains, small stones, pieces of concrete, particles of metal, or other foreign material may gain access to mains newly laid or repaired. If it is believed that such foreign material may be in the main, all hydrants on the line shall be thoroughly flushed and carefully inspected after flushing to see that the entire valve-operating mechanism of each hydrant is in good condition.

TABLE 1

Required Openings to Flush Pipelines
(40-psi Pressure)

Pipe Size *in.*	2.5 fps Flushing Velocity				4 fps Flushing Velocity		
	Flow *gpm*	Orifice Size *in.*	Hydrant Openings		Flow *gpm*	Hydrant Openings	
			No	Size *in.*		No.	Size *in.*
4	100	$1\frac{5}{16}$	1	$2\frac{1}{2}$	160	1	$2\frac{1}{2}$
6	220	$1\frac{3}{4}$	1	$2\frac{1}{2}$	350	1	$2\frac{1}{2}$
8	390	$1\frac{7}{8}$	1	$2\frac{1}{2}$	630	1	$2\frac{1}{2}$
10	610	$2\frac{3}{16}$	1	$2\frac{1}{2}$	980	1	$2\frac{1}{2}$
12	880	$2\frac{13}{16}$	1	$2\frac{1}{2}$	1,400	2	$2\frac{1}{2}$
14	1,200	$3\frac{1}{8}$	2	$2\frac{1}{2}$	1,920	2	$2\frac{1}{2}$
16	1,565	$3\frac{5}{8}$	2	$2\frac{1}{2}$	2,510	3	$2\frac{1}{2}$
						or: 1	$4\frac{1}{2}$
18	1,980	$4\frac{3}{16}$	2	$2\frac{1}{2}$	3,180	3	$2\frac{1}{2}$
						or: 1	$4\frac{1}{2}$
20	2,450	$4\frac{5}{8}$	3	$2\frac{1}{2}$	3,930	4	$2\frac{1}{2}$
			or: 1	$4\frac{1}{2}$		*or:* 1	$4\frac{1}{2}$
						1	$2\frac{1}{2}$
24	3,510	$5\frac{9}{16}$	4	$2\frac{1}{2}$	5,650	6	$2\frac{1}{2}$
			or: 1	$4\frac{1}{2}$		*or:* 1	$4\frac{1}{2}$
			1	$2\frac{1}{2}$		2	$2\frac{1}{2}$
						or: 2	$4\frac{1}{2}$
30	5,500	7	5	$2\frac{1}{2}$	8,830	3	$4\frac{1}{2}$
			or: 1	$4\frac{1}{2}$		*or:* 2	$4\frac{1}{2}$
			2	$2\frac{1}{2}$		2	$2\frac{1}{2}$
			or: 2	$4\frac{1}{2}$			

Sec. 7—Requirement of Chlorination

Before being placed in service, all new mains and repaired portions of, or extensions to, existing mains shall be chlorinated so that a chlorine re-

sidual of not less than 10 ppm remains in the water after 24 hours' standing in the pipe. Exemption from the requirement of chlorination may be granted by the public health authority having jurisdiction, if distribution system chlorine residuals persist throughout the new main and are of sufficient magnitude so that samples of the water delivered by the new main meet the approval of the public health authority.

Sec. 8—Form of Applied Chlorine

Any of the following methods of procedure (arranged in order of preference) shall be followed, subject to the approval of the engineer:

Liquid chlorine gas–water mixture	Sec. 9
Direct chlorine feed	Sec. 9
Calcium or sodium hypochlorite and water mixture	Sec. 10
Chlorinated lime and water mixture	Sec. 10

Sec. 9—Liquid Chlorine

A chlorine gas–water mixture shall be applied by means of a solution-feed chlorinating device, or, if approved by the engineer, the dry gas may be fed directly through proper devices for regulating the rate of flow and providing effective diffusion of the gas into the water within the pipe being treated. Chlorinating devices for feeding solutions of the chlorine gas or the gas itself must provide means for preventing the backflow of water into the chlorine cylinder.

Sec. 10—Chlorine-bearing Compounds in Water

On approval of the engineer, a mixture of water and a chlorine-bearing compound of known chlorine content may be substituted for liquid chlorine.

10.1. *Compounds to be used.* The chlorine-bearing compounds that may be used are: [1] calcium hypochlorite,* [2] chlorinated lime,† and [3] sodium hypochlorite.‡

The use of chlorinated lime (which is low in available chlorine content) increases the sludge problem and may interfere with feeder operation. Exposure to the atmosphere and sunlight results in the loss of chlorine before or after being mixed with water.

10.2. *Preparation of mixture.* High-test calcium hypochlorite or bleaching powder must be prepared as a water mixture for introduction into the water mains. The powder should first be made into a paste and then thinned to approximately a 1 per cent chlorine solution (10,000 ppm). The preparation of a 1 per cent chlorine solution requires the following proportions of powder to water:

Product	Amount of Compound	Quantity of Water *gal*
High-test calcium hypochlorite (65–70% Cl)	1 lb	7.50
Chlorinated lime (32–35% Cl)	2 lb	7.50
Liquid laundry bleach (5.25% Cl)	1 gal	4.25

Table 2 gives the amount of chlorine required for each 100 ft of pipe of various sizes.

Sec. 11—Point of Application

The preferred point of application of the chlorinating agent is at the begin-

* Comparable to commercial products known as "HTH," "Perchloron," and "Pittchlor."

† Frequently called chloride of lime and known to industry as "bleaching powder."

‡ Known commercially as "liquid laundry bleach."

ning of the pipeline extension or any valved section of it and through a corporation stop inserted by the owner (except in new distribution systems) in the top of the newly laid pipe. The water injector for delivering the chlorine-bearing water into the pipe should be supplied from a tap on the pressure side of the gate valve controlling the flow into the pipeline extension. In a new system, application of chlorine may be made advantageously at the pumping station, the elevated tank, the standpipe, or the reservoir.

TABLE 2

Chlorine Requirements for 100-ft Lengths of Various Sizes of Pipe

Pipe Size *in.*	Volume of 100-ft Length *gal*	Amount Required to Give 25 ppm Cl	
		100% Chlorine *lb*	1% Chlorine Water Solution *gal*
4	65.3	0.0135	$\frac{1}{6}$
6	146.5	0.0305	$\frac{3}{8}$
8	261.0	0.054	$\frac{2}{3}$
10	408.0	0.085	1
12	588.7	0.120	$1\frac{1}{2}$

When properly cleaned first, these units are thus chlorinated adequately.

Sec. 12—Rate of Application

Water from the existing distribution system or other source of supply shall be controlled so as to flow slowly into the newly laid pipeline during the application of chlorine. The rate of chlorine mixture flow shall be in such proportion to the rate of water entering the pipe that the chlorine dose applied to the water entering the newly laid pipe shall produce at least 10 ppm after 24 hours' standing. This may be expected with an application of 25 ppm, although some conditions may require more. In application, those persons familiar with the normal chlorine demand of the water and the conditions of the job are best qualified to determine the dosage required. When the results obtained are not in line with past experiences, however, they should be interpreted as evidence that swabbing of the pipe before installation or that flushing of the pipe was inadequately performed.

A convenient method of determining the rate of flow of water into the line to be treated is to start with the line full of water and measure the rate of discharge at a hydrant with a pitot gage. Greater flexibility is made possible by providing a series of orifices to give accurate gage readings at high and low flows.

Sec. 13—Preventing Reverse Flow

Valves shall be manipulated so that the strong chlorine solution in the line being treated will not flow back into the line supplying the water. Check valves may be used, if desired.

Sec. 14—Retention Period

Treated water shall be retained in the pipe long enough to destroy all nonspore-forming bacteria. This period should be at least 24 hours and should produce no less than 10 ppm at the extreme end of the line at the end of the retention period.

NOTE: If the circumstances are such that a shorter retention period must be used, the chlorine concentration shall be increased accordingly. For instance, for a contact period of 1 hour, a 100-ppm chlorine concentration is required. Under these conditions, special care should be taken to avoid attack on

pipes, valves, hydrants, and other appurtenances.

Sec. 15—Chlorinating Valves and Hydrants

In the process of chlorinating newly laid pipe, all valves or other appurtenances shall be operated while the pipeline is filled with the chlorinating agent.

Sec. 16—Final Flushing and Test

Following chlorination, all treated water shall be thoroughly flushed from the newly laid pipeline at its extremities until the replacement water throughout its length shall, upon test, be proved comparable in quality to the water served the public from the existing water supply system and approved by the public health authority having jurisdiction. This satisfactory quality of water delivered by the new main should continue for a period of at least 2 full days as demonstrated by laboratory examination of samples taken from a tap located and installed in such a way as to prevent outside contamination. Samples should never be taken from an unsterilized hose or from a fire hydrant, because such samples will seldom meet bacteriological standards.

Sec. 17—Repetition of Procedure

Should the initial treatment fail to result in the conditions specified in Sec. 16, the original chlorination procedure shall be repeated until satisfactory results are obtained. *Or:*

A free available chlorine residual of not less than 0.4 ppm shall be maintained throughout the entire length of the new main. This permits the immediate use of water from the new main so long as an 0.4-ppm free available chlorine residual is present. The treatment shall continue until the samples on two successive days shall be comparable in quality to the water served the public from the existing water supply system. *Or:*

A combined available chlorine residual of not less than 1.0 ppm shall be maintained throughout the entire length of the new main. This permits the immediate use of water from the new main so long as 1.0 ppm combined available chlorine is present. The treatment shall continue until samples on two successive days shall be comparable in quality to the water served the public from the existing water supply system.

Sec. 18—Procedure When Repairing or Cutting Into Existing Lines

18.1. *General.* The location of a break cannot be forecast. Distribution valve spacing and the position of cutins and breaks relative to hydrants present a complexity of combinations. Only a thoroughly trained, ingenious, and experienced person should be placed in charge of disinfection following the opening of a water main, whether the opening was accidental or by design.

18.1.1. *Trench pollution.* Whether an old line is opened by accident or design, the excavation is always wet and frequently badly contaminated. The likelihood of serious contamination should be taken into account in planning disinfection.

NOTE: The procedure outlined in this section applies in particular to breaks that involve partial or total dewatering of mains. In the event of minor leaks or breaks that are repaired with clamping devices while the mains remain full of water under pressure, the leak should remain exposed while the clamping device is applied. The gasket, which comes in contact with the break, shall be properly disinfected

with a strong hypochlorite solution before it is clamped to the pipe.

18.1.2. *Need for haste.* There is always need for haste in putting an old line back into service. The importance of the service rendered by the line is a significant factor in determining the methods of disinfection that ought to be used.

18.2. *Pipe and packing material.* Packing material, pipes, fittings, and valves should be handled and treated in the same manner as recommended for new mains under Sec. 1 through Sec. 5. The minimum recommended treatment is swabbing the interior of the pipe or fitting with a strong (20–25 ppm) solution of hypochlorite.

18.3. *Flushing.* Flushing shall always follow the closing of an opening in a main; however, a reasonable contact time with the disinfectant shall precede the flushing operation. If valving and hydrant locations permit, flushing from two directions is helpful. Flushing should be continued until discolored water is eliminated. Flushing through existing hydrants is most convenient, but unusual contamination hazards may require the installation of special flushing taps.

18.4. *Disinfection.* In locations where the direction of flow is known, and where tests show that the water which will flow into the newly installed pipe and fittings contains a substantial free available chlorine residual (approximately 0.5 ppm), it is probable that no contamination will reach a customer. Proximity of customers' taps and the resulting contact period must be taken into consideration.

18.4.1. *Application of chlorine.* Liquid chlorine is the preferred form to be applied, but hypochlorites may be used. The simplest, but least effective, means of disinfection is the direct application of dry hypochlorite, or a heavy slurry of it, on either side of the opening, before the new pipe and fittings are installed.

18.4.2. *Introduction of chlorine.* The solution of chlorine or the suspension of hypochlorites may be introduced through a tap made for the purpose or, more conveniently, through a fire hydrant, when one is available in a suitable location.

18.4.3. *Distribution and flushing.* The chlorine should be added in such a way as to insure that a high concentration (20–25 ppm) reaches every part of the isolated section of the main.

18.4.4. *Contact time and flushing.* The maximum permissible contact period should be used, after which the water bearing strong chlorine should be flushed out before the main is returned to service.

18.4.5. *Sampling.* In order to develop confidence in the efficacy of the procedures employed and to provide a protective historical record, sampling and laboratory examination of the water should be carried on for some days, as determined by the engineer in charge. A single sample taken immediately after chlorination is not informative unless the results are unfavorable.

Selected Procedures for Analyzing Aquifer Test Data

By Russell H. Brown

A paper presented on May 14, 1953, at the Annual Conference, Grand Rapids, Mich., by Russell H. Brown, Hydraulic Engr., Ground Water Branch, Water Resources Div., U.S. Geological Survey, Washington, D.C. Publication of this article has been authorized by the Director, U.S. Geological Survey.

THE purpose of this paper is to show, through the liberal use of sketches and diagrams, a few of the ways in which it is possible to learn a great deal about the country's ground water reservoirs. The methods described will be limited to those involving the use of water wells. It should be mentioned at the outset that some of the illustrations have been simplified to make it easier to convey important ideas that can be readily understood and compared with phenomena observed by operators of ground water supply developments.

As is well known, studies of ground water resources are continually being made by the Ground Water Branch of the U.S. Geological Survey in cooperation with many state and local agencies throughout the country. This work is directed toward locating ground water reservoirs and learning as much as possible about them, including their extent and their ability to store and transmit water. Examination and comparison of the methods used in making these studies would reveal no completely stereotyped pattern of procedure. In fact, each study would appear to involve its own peculiar combination of geologic and hydrologic factors requiring individual methods of analysis. Over the years, therefore, the USGS has developed quite a large store of qualitative and quantitative geologic and hydrologic methods of study. In this paper, it will be possible to demonstrate only a select few of the many methods used in determining the hydrologic characteristics of ground water reservoirs.

Definition of Terms

Before going further, it will be desirable to introduce and define a few terms that will facilitate an understanding of what is to follow.

Aquifer. A ground water reservoir may be more concisely termed an "aquifer," which is simply defined as a geologic formation, a part of a formation, or a group of formations that is water bearing. Figure 1 shows a generalized sectional view of an actual artesian aquifer in the Houston, Tex., area. The stippled pattern denotes the water-bearing aquifer sands and the dashed-line pattern designates the confining clay materials above and below. Water enters the aquifer chiefly by precipitation on the land surface in the zone labeled "Principal Recharge Area," and water is withdrawn from the aquifer through wells developed mainly within the Houston city limits.

It might be helpful to point out that the word "artesian" signifies that the water in the aquifer occurs under pressure. In other words, if a well is drilled into the aquifer, water will rise in the well to some point above the top of the aquifer but not necessarily up to or above the land surface. Figure 1 serves to illustrate two important ways in which an aquifer functions. First, it transmits water from a recharge area to areas of principal withdrawal. In this illustration, the horizontal scale shows that the distance involved is of the order of tens of miles. Actually, for some aquifers in the United States, the distance may be of the order of several hundred miles. In transmitting water a considerable distance, however, an aquifer functions importantly in a second manner, by virtue of the amount of water in transient storage. If it is recognized that the rate of water movement through the aquifer may be only a few inches or feet per day, the significance of the storage function is obvious. For only a 1-ft thickness of water-bearing sand, tens of millions of gallons of water may be in storage in each square mile of aquifer area.

In Fig. 2 is given a generalized sectional view of an artesian aquifer on Long Island, N.Y. Again, the stippled pattern denotes the water-bearing aquifer sands and the dashed-line pattern the confining clays above. In this example, the aquifer is underlain by relatively impermeable bedrock. The situation here is not as clear cut as that shown in the previous section, but the aquifer still functions in the same two important ways already discussed. It is recharged—in general, near its Long

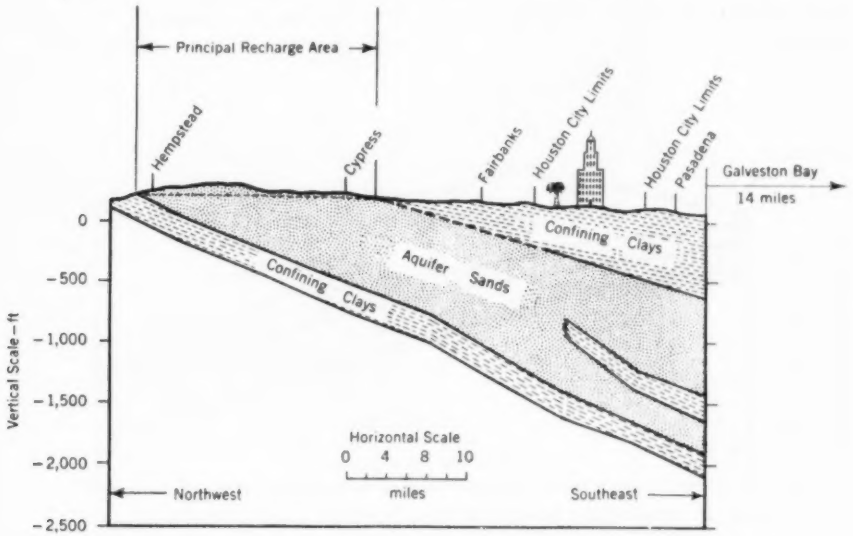

Fig. 1. Generalized Section of Artesian Sand Aquifer (Houston Area)

Water enters chiefly by precipitation on the land surface in the "Principal Recharge Area" and is withdrawn mainly through wells within Houston's city limits.

Island Sound extremity—by water entering through discontinuities or relatively permeable zones in the upper confining clays, although the exact individual locations of these recharge areas are not yet known. The water thus recharged is transmitted down dip through the aquifer toward the Atlantic Ocean and, to a lesser extent, northward to Long Island Sound, serving a number of areas of withdrawal en route. During the process, a tremendous volume of water is in transient storage.

is designated in survey usage by P. In Fig. 3 is repeated the familiar sectional view, this time in perspective, of aquifer sands confined above and below by relatively impermeable clays. In the exposed end of the aquifer, there is shown an opening, A, 1 ft square. Suppose some kind of collar were thrust into this opening so that, as water flows through the aquifer, the amount that came through the collar would be only that percolating through the rear vertical wall of the opening. The coefficient of permeability would then be ex-

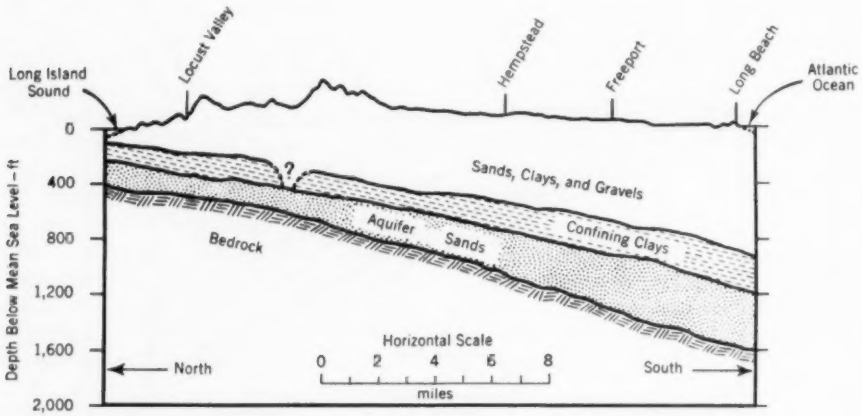

Fig. 2. Generalized Section of Artesian Sand Aquifer (Long Island)

Water enters through breaks or relatively permeable zones in the upper confining clays and is withdrawn through wells at locations scattered across the island.

It is pertinent to mention that such generalized sections as those presented in Fig. 1 and 2 can be drawn only after the collection, review, and assimilation of many well records and logs.

Three other terms requiring definition might be labeled the hydraulic properties of an aquifer. The diagrammatic sketch in Fig. 3 should aid in their understanding.

Coefficient of permeability. The coefficient of permeability of an aquifer

pressed as the number of gallons per day that would flow through aquifer opening A under a unit hydraulic gradient. The coefficient is defined for use at a temperature of 60°F. For field use, the correction to 60°F is neglected, and the "field coefficient" expresses the flow of ground water at the prevailing water temperature. The significance of a unit hydraulic gradient can be understood by noting in the diagram the pair of observation wells (or

piezometer tubes) placed 1 ft apart and extending into the aquifer sands. If a unit hydraulic gradient prevails, there should be a 1-ft differential in the water levels observed in these piezometer tubes—that is, a 1-ft drop of water level in 1 ft of flow distance. Actually, this gradient is many times steeper than the hydraulic gradients found in nature, where a drop of a few feet per mile of flow distance is more nearly the usual order of magnitude. The coefficient of permeability of an aquifer, then, can be expressed in "gallons per day per square foot" under a unit hydraulic gradient.

Coefficient of transmissibility. Related to the permeability of an aquifer is the coefficient of transmissibility, commonly designated by T. In the exposed end of the aquifer in Fig. 3, opening B is 1 ft wide and extends the full thickness or height, m, of the aquifer. With some kind of collar thrust into this opening, the water coming through is again only that which percolates through the rear vertical wall of the opening. The coefficient of transmissibility would be the number of gallons per day flowing through aquifer opening B under a unit hydraulic gradient (at the prevailing water temperature). Thus, the coefficient of transmissibility is expressed in "gallons per day per foot" under a unit hydraulic gradient. It is easy to see

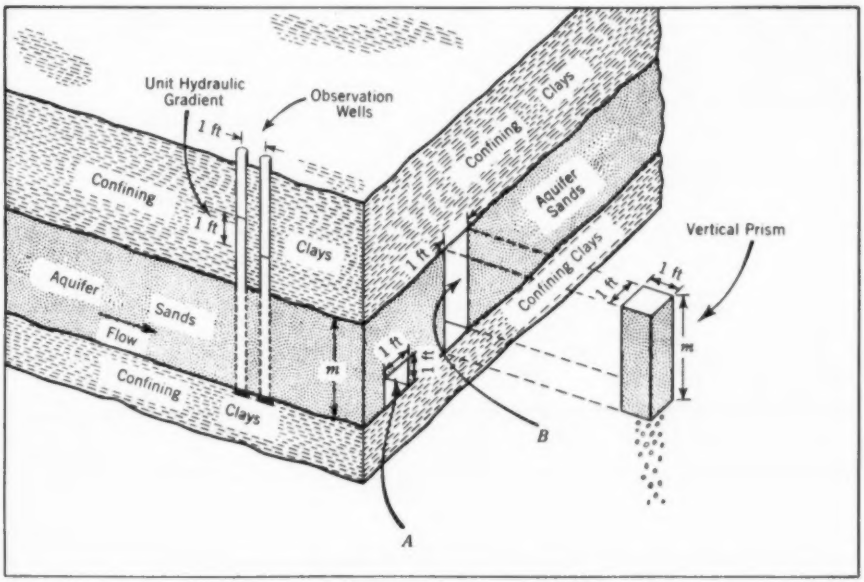

Fig. 3. Hydraulic Properties of Aquifer

Opening A *is 1 ft square and opening* B *has a width of 1 ft and a height equal to the thickness,* m, *of the aquifer. The dimensions of the vertical prism are 1 ft by 1 ft by* m. *In the upper left portion of the figure, there is illustrated diagrammatically the unit hydraulic gradient, a 1-ft drop in head in 1 ft of flow distance*

that the coefficient of transmissibility can be obtained merely by multiplying the field coefficient of permeability by the aquifer thickness; that is, $T = Pm$.

Coefficient of storage. The third important hydraulic property of an aquifer is its coefficient of storage, commonly designated by S. It is difficult to give a physical interpretation to this property, but a reasonable understanding of its significance can perhaps be gained by referring in Fig. 3 to a unit vertical prism pulled out of the aquifer and displayed at the right of the diagram. This vertical prism has a cross-sectional area of 1 sq ft and a height equal to the thickness, m, of the aquifer. If the piezometric head on this saturated prism is lowered 1 ft, a small amount of water will be released from storage owing to a slight expansion of the water itself and to slight structural changes of the prism skeleton. The coefficient of storage is defined as the relative amount of water released from storage in a unit vertical prism of the aquifer as the piezometric head declines 1 ft. It is ordinarily expressed as an

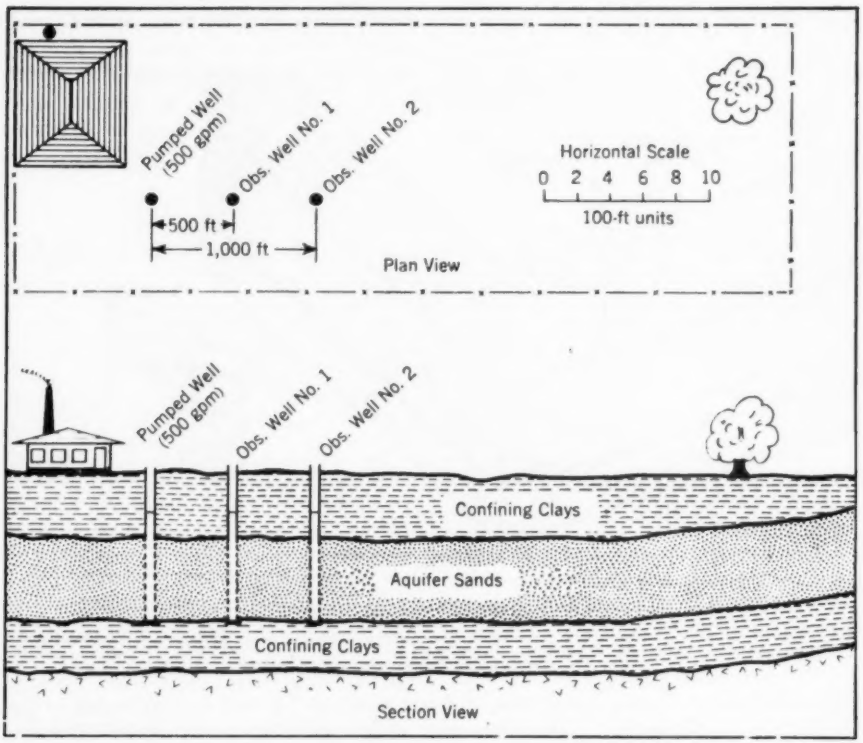

Fig. 4. Hypothetical Test Situation (Infinite Aquifer)

In this hypothetical situation, one well will be pumped at the rate of 500 gpm, and water level changes will be noted in observation wells No. 1 and 2.

absolute decimal fraction and, for artesian conditions, is a very small value, often in the range of 10^{-5} to 10^{-3}. Aquifer testing methods are primarily concerned with the coefficients of transmissibility and storage.

Preliminary Considerations

All the methods about to be considered are designed to yield information on aquifer performance and not on well performance. There are certain features common to all the testing and analytical methods to be presented. As already intimated, each method will involve turning a pumped well on or off and observing what happens to the water levels in nearby observation wells. The discussion will be restricted entirely to artesian conditions, largely for ease of presentation. Each method will involve the use of the Theis (*1*) nonequilibrium formula, which derives its name from the man who first developed it and from the fact that it takes into account the time that has elapsed since pumping began or since pumping ceased. Finally, each method will relate solely to those particular uses of the Theis formula that consider variations in drawdown with the passing of time.

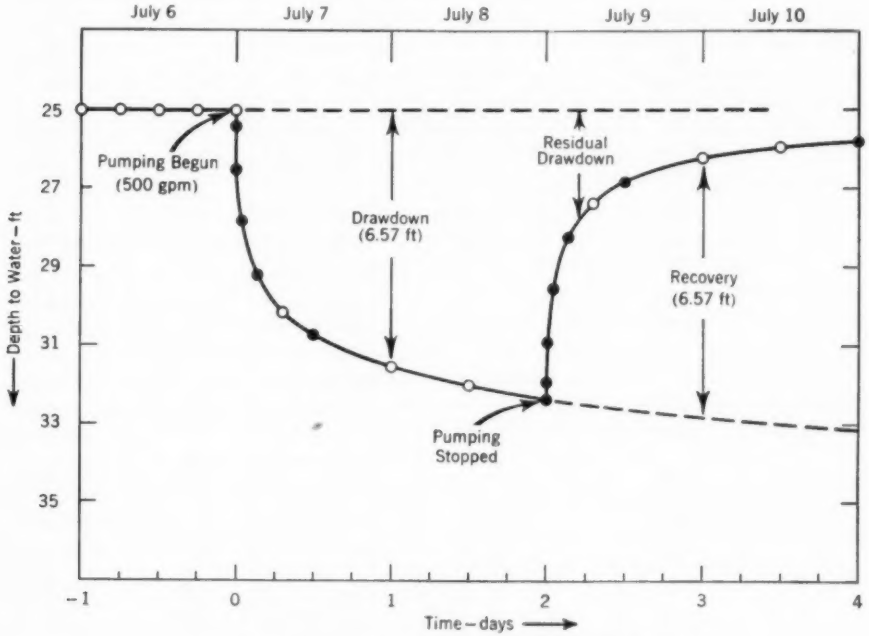

Fig. 5. Hydrograph for Observation Well No. 1

Drawdown data are plotted on the left curve, recovery data on the right. These data are for observation well No. 1, located 500 ft from the pumped well. Points indicated by ● are used in later analysis plots. Arrows indicate direction of increasing scale values.

TABLE 1

Drawdown Test Data for Observation Wells

Date (July 1952)	Hour	Elapsed Time		$\frac{t}{r^2}$	Drawdown* s ft	Depth to Water ft
		min	t days			
		Well No. 1 (r = 500 ft)				
5	2400					25.00
6	0600					25.00
	1200					25.00
	1800					25.00
	2400†	0	0	0	0	25.00
7	0004	4	0.00278	1.1×10^{-5}	0.44	25.44
	0015	15	0.0104	4.2×10^{-5}	1.50	26.50
	0055	55	0.038	1.5×10^{-7}	2.83	27.83
	0305	185	0.13	5.2×10^{-7}	4.22	29.22
	0600	360	0.25	1.0×10^{-6}	4.96	29.96
	1200	720	0.50	2.0×10^{-6}	5.75	30.75
	2400	1,440	1.0	4.0×10^{-6}	6.57	31.57
8	1200	2,160	1.5	6.0×10^{-6}	7.04	32.04
	2400	2,880	2.0	8.0×10^{-6}	7.32	32.32
		Well No. 2 (r = 1,000 ft)				
5	2400					25.10
6	0600					25.10
	1200					25.10
	1800					25.10
	2400†	0	0	0	0	25.10
7	0030	30	0.0208	2.1×10^{-5}	0.89	25.99
	0155	115	0.080	8.0×10^{-5}	2.16	27.26
	0640	400	0.278	2.8×10^{-7}	3.53	28.63
	2400	1,440	1.0	1.0×10^{-6}	4.94	30.04
8	2400	2,880	2.0	2.0×10^{-6}	5.75	30.85

* Values in this column are derived from the depth-to-water measurements made in the observation well and given in the next column.
† Pumped well begins discharging at 500 gpm.

For the successful application and use of these methods, the aquifer should be homogeneous and isotropic—that is, it should be of uniform structure and exhibit the same physical and hydraulic properties in all directions. The aquifer theoretically should be of infinite extent, although it is recognized that an infinite aquifer is not found in nature. Practically, therefore, the thickness and actual extent of the aquifer should be known, to permit the best

possible interpretation of the test data. Ideally, any wells that are used should fully penetrate the aquifer. Some departures from this requirement can be tolerated, but, in any event, the construction details of the wells used should be known or determined. Operation of any pumps in the area should be stabilized before an aquifer test is begun and maintained that way for the duration of the test. During the test, well pumping should be at a steady, unvarying rate carefully measured. Water level observations should be accurately made and the time of each observation exactly determined. Finally, the data should be carefully computed and plotted.

A demonstration of the test and analytical methods requires a hypothetical test setup. It will be convenient to begin by adopting arbitrarily the physical situation shown in plan and section in Fig. 4. This illustration again depicts the familiar sand aquifer confined above and below by relatively impermeable clays. It is proposed to pump one well at 500 gpm and observe water level changes in two nearby wells, numbered 1 and 2. The wells proposed for use fully penetrate the aquifer and, insofar as can be determined from the sectional view, the aquifer extends out to infinity. There is no evidence of any nearby wells whose pumping might affect the test results. The observation wells could have been located anywhere in the general vicinity of the pumped well, but, for convenience, they were placed in a straight line.

Drawdown Method

As its name implies, the drawdown method involves pumping one well, in the hypothetical test setup, and observing what happens to the water levels in the two nearby wells. It might be helpful first to show what may be expected to happen in one of the observation wells during the drawdown test and to demonstrate what is meant by the term drawdown. Figure 5 is a hydrograph—a plot of water level versus time—for observation well No. 1 (see Table 1). Only the left half of Fig. 5 need be considered at this point. Water level measurements were made for a day prior to the start of the test in order to determine whether they indicated any preexisting upward or downward trend that would have to be considered during the test. Again for convenience, it was assumed that there was no upward or downward trend of water levels in the area, and the measurements are shown plotted along a horizontal line. Referring to the portion of the hydrograph after pumping started, the drawdown represents the difference between the water level observed in the well and the level at which the water would have stood had no pumping occurred. In the drawdown method, then, similar data will be collected for the two observation wells and analyzed as the test proceeds. In performing the analysis, two kinds of solutions are available.

Type Curve Solution

As already stated, the Theis nonequilibrium formula is the basis for all the analytical methods to be considered in this paper. In absolute form, the Theis equation is:

$$s = \frac{Q}{4\pi T} \int_{\frac{r^2 S}{4Tt}}^{\infty} \frac{e^{-u}}{u}\, du \quad \ldots\ldots (1)$$

in which $u = \frac{r^2 S}{4Tt}$, s is the drawdown at any point under study in the vicin-

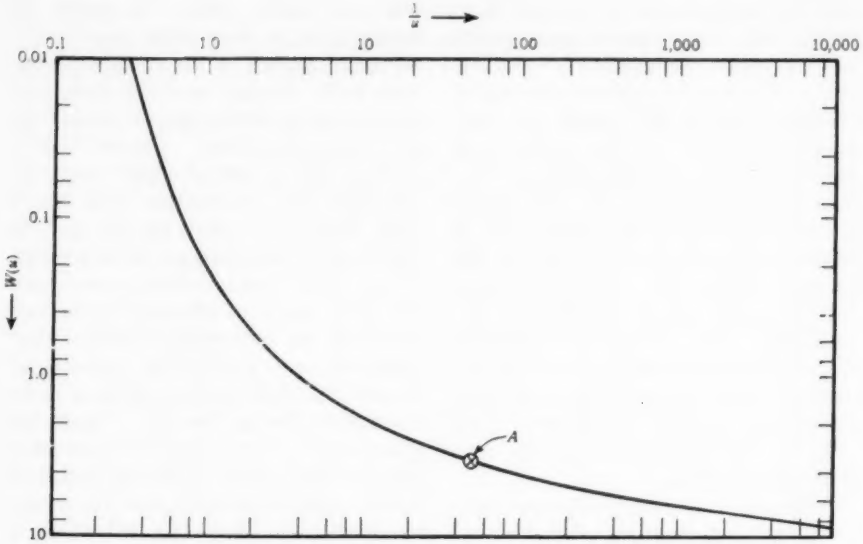

Fig. 6. Theis Type Curve (Drawdown Data Analysis)

Point A on the curve is at $\frac{1}{u} = 50$. *Basic formulas for using this curve and computing coefficients of transmissibility,* T, *and storage,* S, *are:*

$$T = \frac{114.6Q}{s} W(u); \quad S = \frac{T\left(\frac{t}{r^2}\right)}{1.87\left(\frac{1}{u}\right)}$$

ity of a discharging well, Q is the rate of discharge of the well, T is the coefficient of transmissibility of the aquifer, S is the coefficient of storage of the aquifer, r is the distance from the discharging well to the point where the drawdown is being observed, t is the time elapsed since discharge began, and e is the natural-logarithm base. Survey usage favors expressing s in feet, Q in gallons per minute, T in gallons per day per foot, r in feet, and t in days. In these units, the Theis equation has the form:

$$s = \frac{114.6Q}{T} \int_{\frac{1.87r^2S}{Tt}}^{\infty} \frac{e^{-u}}{u}\, du \quad \ldots (2)$$

and $u = \dfrac{1.87r^2S}{Tt}$. Equation 2 can more conveniently be written:

$$s = \frac{114.6Q}{T} W(u) \quad \ldots \ldots (3)$$

in which $W(u)$ replaces the integral expression and is called the "well function of u." The outward appearance of Eq 3 implies a simple and direct means of solving for T. Unfortunately, however, T is also involved in the $W(u)$ term, so that a direct solution is not possible. It is convenient, therefore, to get around this difficulty by the use of a type curve or graphical solution. In Eq 3, the only variable

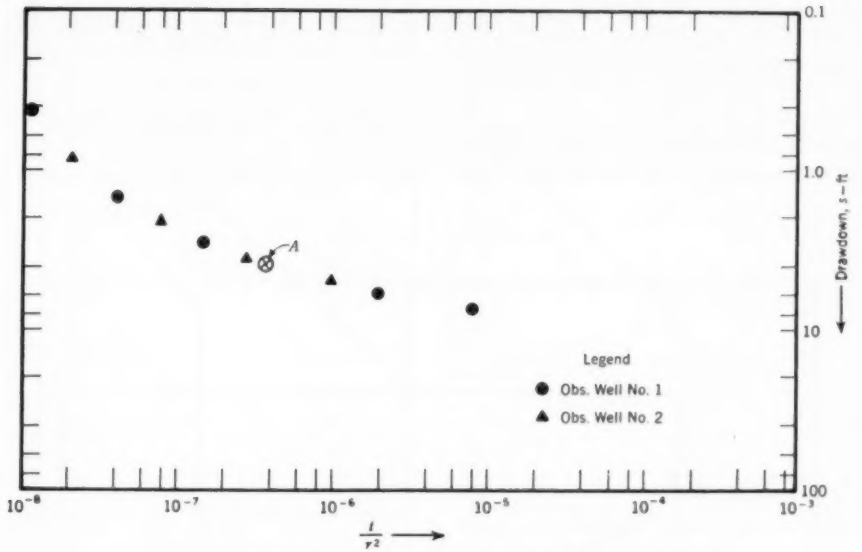

Fig. 7. Plot of Drawdown Test Data (Type Curve Solution)

Drawdown data from the two observation wells are plotted logarithmically. Point A *(at* $\frac{1}{u} = 50$ *on the Theis type curve) has been introduced as a point of reference.*

terms will be the drawdown, s, and the well function, $W(u)$. Similarly, in the equation for u, the only variable terms will be u, r, and t. The significance of these facts is more apparent if the two equations involved are rewritten in slightly different form:

$$W(u) = \left[\frac{T}{114.6Q}\right] s \quad \ldots\ldots (4)$$

$$\frac{1}{u} = \left[\frac{T}{1.87S}\right] \frac{t}{r^2} \quad \ldots\ldots (5)$$

The brackets enclose all the terms that are constant. The similarity of form exhibited by Eqs. 4 and 5 should suggest that, ignoring the bracketed coefficients, which are constants, the term $W(u)$ will vary with the term $\frac{1}{u}$ in the same manner as s will vary with $\frac{t}{r^2}$. In other words, if values of $W(u)$ are plotted against corresponding values of $\frac{1}{u}$, the resulting curve should resemble that of a plot of s values against $\frac{t}{r^2}$ values. Published tables (*2*) give values of $W(u)$ and u (from which $\frac{1}{u}$ can be determined), and, of course, the aquifer test data will provide values of s, t, and r. If these two curves are plotted on arithmetic plotting paper, they will exhibit a general similarity of shape but they will not be identical in shape and curvature. This follows from the fact that the variables in the right halves of Eq 4 and 5 are multiplied by differ-

ent constants. If the two curves are plotted on logarithmic paper, however, multiplication becomes addition, so that differences in the constant multipliers of Eq 4 and 5 merely cause relative displacements in the horizontal and vertical scales of the two plots.

$$\log W(u) = \log\left[\frac{T}{114.6Q}\right] + \log s \quad (6)$$

$$\log \frac{1}{u} = \log\left[\frac{T}{1.87S}\right] + \log \frac{t}{r^2} \quad (7)$$

By preparing a logarithmic plot, with values of $W(u)$ as ordinates and values of $\frac{1}{u}$ as abscissas, there is developed what is called a type curve for the Theis equation, as shown in Fig. 6. The curve has the same general shape and trend as the first half of the hy-

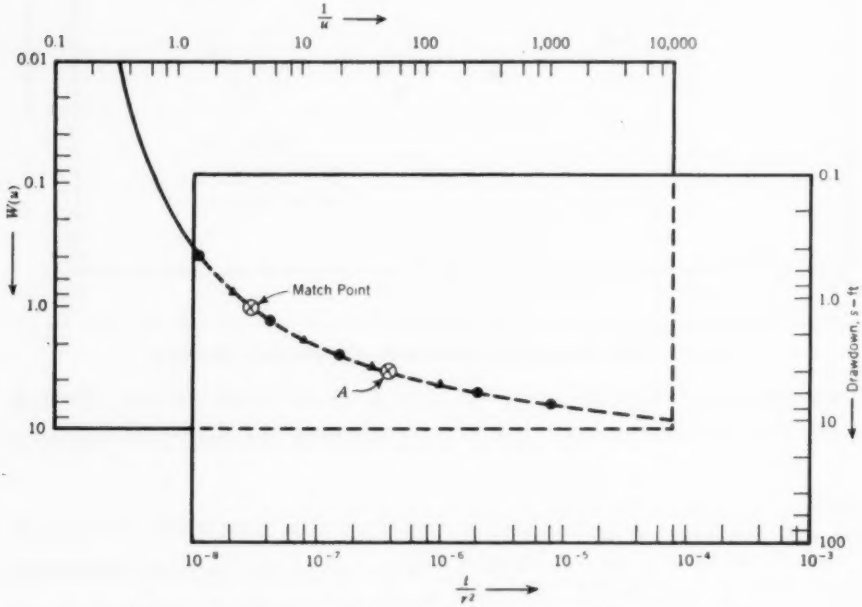

Fig. 8. Drawdown Test Data Superposed on Theis Type Curve

With the coordinate axes parallel, Fig. 7 has been superposed on Fig. 6. A convenient match point is selected—in this instance, the match point coordinates are: $\left[s = 1.15, \frac{t}{r^2} = 2.9 \times 10^{-8}\right]$ *and* $\left[W(u) = 1.0, \frac{1}{u} = 3.85\right]$. *These coordinates are then substituted in Eq 8 and 9, to obtain* T *and* S, *respectively.*

Use of logarithmic plotting paper has the added advantages of magnifying the low values in the data array and permitting coverage of large ranges in values on relatively small sheets.

Equations 4 and 5 may be rewritten in logarithmic form:

drograph already seen in Fig. 5. The arrow shown with each scale label indicates the direction in which the same shape and trend as the type curve. The solution now requires superposing the data plot on the type

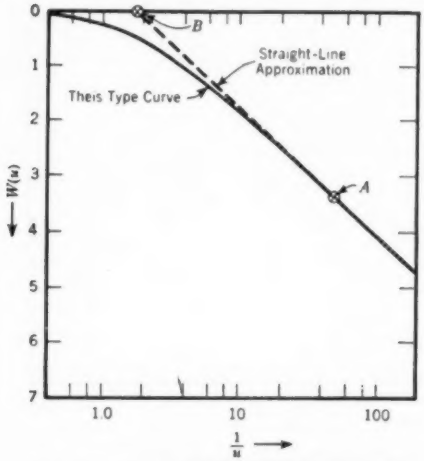

Fig. 9. Straight-Line Approximation (Drawdown Data Analysis)

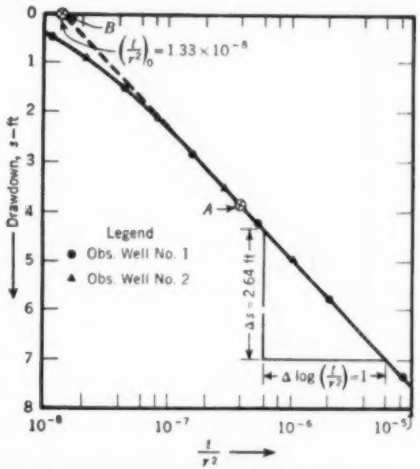

Fig. 10. Plot of Drawdown Test Data (Straight-Line Solution)

For values of $\frac{1}{u}$ *greater than 50, the equation* $W(u) = \log_e \frac{1}{u} - 0.5772$ *is essentially linear.* W(u) *is plotted arithmetically and* $\frac{1}{u}$ *logarithmically. Point* A *is at* $\frac{1}{u} = 50$. *The straight line extended intercepts the* W(u) = 0 *line at Point* B, *where* $\frac{1}{u} = 1.78 = e^{0.5772}$.

scale values increase. Similarly, a logarithmic plot is prepared, as shown in Fig. 7, using values of s as ordinates and values of $\frac{t}{r^2}$ as abscissas. These values are worked out from the aquifer test data—in this instance, from drawdown data collected at observation wells No. 1 and 2, as shown in Table 1. Observe that the data plot has the

Point A *is at* $\frac{1}{u} = 50$. *Point* B, *the zero intercept of the straight line extended, is at* $\left(\frac{t}{r^2}\right)_0 = 1.33 \times 10^{-8}$. *With* $\Delta \log \frac{t}{r^2}$ *taken as 1, the value of* Δs *is found from the graph.* T *and* S *can then be obtained by substitution in Eq 15 and 17:*

$$T = \frac{264Q}{\Delta s} = \frac{264\ (500)}{2.64}$$

$$= 50{,}000\ gpd/ft$$

$$S = 0.301T\left(\frac{t}{r^2}\right)_0$$

$$= 0.301\ (50{,}000)(1.33 \times 10^{-8})$$

$$= 2.0 \times 10^{-4}$$

curve, keeping the coordinate axes parallel, in such a manner that a good matching position is found, as shown

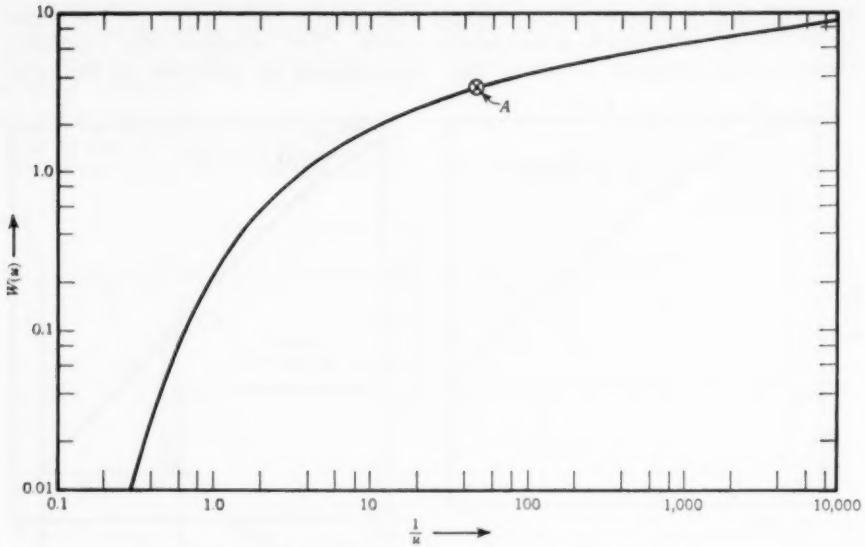

Fig. 11. Theis Type Curve (Recovery Data Analysis)

Point A *on the curve is at* $\frac{1}{u} = 50$. *This curve is the same as the one in Fig. 6 but is inverted to be comparable to a rising water level trend. Again the basic formulas for computing* T *and* S *are:*

$$T = \frac{114.6Q}{s} W(u); \qquad S = \frac{T\left(\frac{t}{r^2}\right)}{1.87\left(\frac{1}{u}\right)}$$

in Fig. 8. In the matched position, the scales of one graph will prove to be displaced with respect to the scales of the other. This follows from the nature of Eq 6 and 7, which indicate, respectively, displacement of the vertical scale by the amount $\log\left[\frac{T}{114.6Q}\right]$ and displacement of the horizontal scale by the amount $\log\left[\frac{T}{1.87S}\right]$. With the data plot matched to the type curve, a convenient match point anywhere on the curve, or anywhere on the graph sheet for that matter, is selected for use in computing the coefficients of transmissibility and storage. In Fig. 8, a match point was arbitrarily taken on the curve such that its coordinates, on the data and type curve plots respectively, are $\left[s = 1.15, \quad \frac{t}{r^2} = 2.9 \times 10^{-8}\right]$ and $\left[W(u) = 1.0, \frac{1}{u} = 3.85\right]$. The solution is completed by substituting these coordinate values in appropriately re-

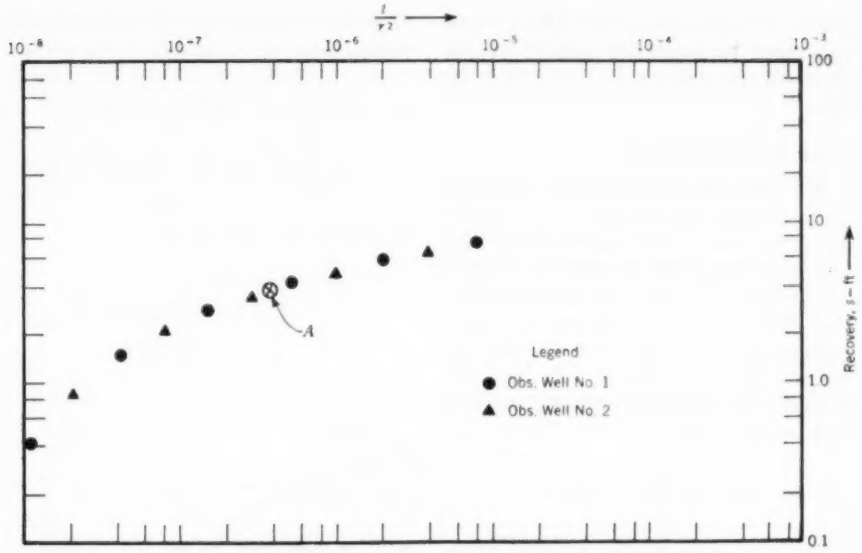

Fig. 12. Plot of Recovery Test Data (Type Curve Solution)

This curve is the inverse of the one in Fig. 7. Point A is at $\frac{1}{u} = 50$.

arranged forms of Eq 4 and 5. Thus:

$$T = \frac{114.6Q}{s} W(u) \quad \ldots\ldots (8)$$

and, by substitution:

$$T = \frac{114.6\ (500)}{1.15}\ (1.0)$$
$$= 50{,}000 \text{ gpd/ft}$$

Similarly:

$$S = \frac{T\left(\frac{t}{r^2}\right)}{1.87\left(\frac{1}{u}\right)} \quad \ldots\ldots (9)$$

and, by substitution:

$$S = \frac{50{,}000\ (2.9 \times 10^{-8})}{1.87\ (3.85)} = 2.0 \times 10^{-4}$$

Presentation of the many details and variations of the type curve form of solution is not attempted in this paper. The interested reader may explore further in the reference literature. He should not be too dismayed, however, in reading other publications, if the methods of analysis described, or the plots and illustrations presented, appear at variance with those in this paper. Scientists in the field of ground water hydrology may develop individual preferences in their analytical methods, but the fundamental principles and theory are common to all. Thus, it makes little difference, for example, whether a type curve is prepared by plotting values of $W(u)$ against $\frac{1}{u}$ or by plotting $W(u)$ against u; or whether a data curve is prepared by plotting values of s against $\frac{t}{r^2}$ or s against $\frac{r^2}{t}$, or simply against

t or r. The particular method favored will often be governed largely by the physical plant setup for collecting the data.

Straight-Line Solution

A second form of solution available for analyzing aquifer test data is really an abbreviated and approximate version of the type curve solution already considered. It will be remembered that the term $W(u)$ given in Eq 3 represents the integral expression appearing in Eq 1 and 2. In its integrated form, this expression is equivalent to the series:

$$W(u) = \left(-0.5772 - \log_e u + u - \frac{u^2}{2 \times 2!} + \frac{u^3}{3 \times 3!} - \frac{u^4}{4 \times 4!} + \cdots\right) \quad (10)$$

in which $\log_e u$ is the natural logarithm of u and 0.5772, known as Euler's constant, can be written in natural logarithmic form as $\log_e e^{0.5772}$. Inasmuch as $u = \frac{r^2 S}{4Tt}$ or, in slightly different form, $u = \frac{S/4T}{t/r^2}$, it can be seen that, for large values of $\frac{t}{r^2}$ as compared with the value of $\frac{S}{4T}$, the value of u will be small. Because the term $\frac{S}{4T}$ is theoretically a constant, which will evidently have a low value, it will not require inordinately large values of t or small values of r to give small values of u. In the series expression given in Eq 10, if u becomes sufficiently small, the series can be satisfactorily approximated by using only its first two terms. This approximation is tolerable, as will be shown, so long as u is less than approximately 0.02—that is, $\frac{1}{u}$ is greater than 50.

Now Eq 1 can be rewritten in approximate form as:

$$s = \frac{Q}{4\pi T}(-0.5772 - \log_e u)$$

$$= \frac{Q}{4\pi T}\left(\log_e \frac{1}{u} - \log_e e^{0.5772}\right)$$

or, substituting $u = \frac{r^2 S}{4Tt}$:

$$s = \frac{Q}{4\pi T}\left(\log_e \frac{4Tt}{r^2 S e^{0.5772}}\right)$$

$$= \frac{Q}{4\pi T} \log_e \frac{2.25Tt}{r^2 S} \quad \ldots\ldots (11)$$

Equation 11 can be rewritten in several different forms (*3*) to accommodate the particular kind of drawdown test data being accumulated. Recognizing that the test under discussion here involves the collection of drawdown data for two observation wells, it will be convenient to modify or rewrite Eq 11 as follows, converting to common logarithms in the process:

$$s = \frac{2.303Q}{4\pi T}\left(\log_{10} \frac{t}{r^2} - \log_{10} \frac{S}{2.25T}\right) \quad (12)$$

The only variables in Eq 12 are the drawdown, s, and the term $\frac{t}{r^2}$; in other words, s varies as the logarithm of $\frac{t}{r^2}$. Thus, if values for these two variable terms are plotted on semilog plotting paper, it can be seen from the form of Eq 12 that a straight-line plot should result.

The success of this procedure still hinges, of course, on the important assumption that $\frac{1}{u}$ is greater than ap-

proximately 50. It might be well to digress for a moment to demonstrate how the critical value of 50 is selected. It may be noted from Eq 10 and the derivation of Eq 11 that, if $W(u)$ is equated only to the first two terms of the series expression, there results a relation showing that $W(u)$ varies as the logarithm of $\frac{1}{u}$. Thus, if the Theis type curve is merely replotted on semilog plotting paper, a straight line should appear beyond some critically large value of $\frac{1}{u}$. Figure 9 has been prepared on semilog paper by plotting values of $W(u)$ on the arithmetic scale against values of $\frac{1}{u}$ on the logarithmic scale. Although, for low values of $\frac{1}{u}$, the points plot along a curve, it will be observed that, for values of $\frac{1}{u}$ greater than approximately 50, the points plot as essentially a straight line. Point A in Fig. 9 represents a $\frac{1}{u}$ value of 50 and has the same significance in Fig. 6 and 7.

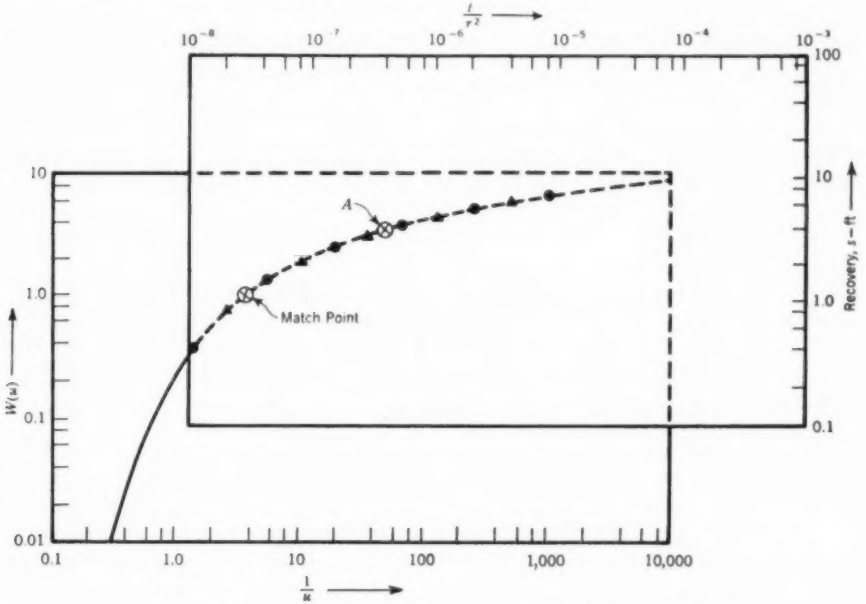

Fig. 13. Recovery Test Data Superposed on Theis Type Curve

Figure 12 has been superposed on Fig. 11 in the same manner as Fig. 7 on Fig. 6. The match point chosen in Fig. 13 has the same coordinates as that in Fig. 8, namely, $\left[s = 1.15, \frac{t}{r^2} = 2.9 \times 10^{-8}\right]$ *and* $\left[W(u) = 1.0, \frac{1}{u} = 3.85\right]$. *As in the drawdown analysis by this method,* T *and* S *(the coefficients of transmissibility and storage, respectively) are found by substituting the match point coordinates in Eq 8 and 9.*

Returning to Eq 12, if s is plotted against $\log_{10} \frac{t}{r^2}$ on semilog plotting paper, the slope of the resulting straight line is represented by the constant quantity preceding the parenthesis, and the zero-drawdown intercept of the straight line is represented by the second term in the parenthesis. The slope of the straight line evidently will be the change in drawdown over a selected segment of the plot divided by the corresponding change in the logarithm of $\frac{t}{r^2}$. This is written in the form $\Delta s / \Delta \log \frac{t}{r^2}$, which can be equated to the constant quantity preceding the parenthesis in Eq 12:

TABLE 2

*Recovery Test Data for Observation Wells**

Date (July 1952)	Hour	Elapsed Time		$\frac{t}{r^2}$	Recovery† s, ft	Extrapolated Depth to Water, ft	Observed Depth to Water, ft
		min	t, days				
			Well No. 1 (r = 500 ft)				
8	2400‡	0	0	0	0	32.32	32.32
9	0004	4	0.00278	1.1×10^{-5}	0.44	32.32	31.88
	0015	15	0.0104	4.2×10^{-5}	1.50	32.34	30.84
	0055	55	0.038	1.5×10^{-7}	2.83	32.36	29.53
	0305	185	0.13	5.2×10^{-7}	4.22	32.41	28.19
	0600	360	0.25	1.0×10^{-6}	4.96	32.46	27.50
	1200	720	0.50	2.0×10^{-6}	5.79	32.59	26.80
	2400	1,440	1.0	4.0×10^{-6}	6.57	32.80	26.23
10	1200	2,160	1.5	6.0×10^{-6}	7.04	32.98	25.94
	2400	2,880	2.0	8.0×10^{-6}	7.32	33.14	25.82
			Well No. 2 (r = 1,000 ft)				
8	2400‡	0	0	0	0	30.85	30.85
9	0030	30	0.0208	2.1×10^{-8}	0.89	30.86	29.97
	0155	115	0.080	8.0×10^{-8}	2.16	30.89	28.73
	0640	400	0.278	2.8×10^{-7}	3.53	30.99	27.46
	2400	1,440	1.0	1.0×10^{-6}	4.94	31.31	26.37
12	2400	5,760	4.0	4.0×10^{-6}	6.57	32.10	25.53

* This recovery test is assumed to follow a 2-day drawdown test.

† Each value in this column is derived by subtracting the measured depth to water (last column) from the predicted or extrapolated depth to water that would have been observed had pumping continued.

‡ Well pumping at 500 gpm is stopped.

$$\frac{2.303Q}{4\pi T} = \frac{\Delta s}{\Delta \log \frac{t}{r^2}}.$$

Solving for the only unknown, T:

$$T = \frac{2.303Q}{4\pi}\left(\frac{\Delta \log \frac{t}{r^2}}{\Delta s}\right) \ldots (13)$$

If the change in drawdown is taken for any portion of the straight line spanning one log cycle, the term $\Delta \log \frac{t}{r^2}$ evidently equals unity. Equation 13 may then be written:

$$T = \frac{2.303Q}{4\pi \Delta s} \ldots\ldots (14)$$

Converting to the usual USGS units, in which Q is expressed in gallons per minute, T in gallons per day per foot, and s in feet, Eq 14 becomes:

$$T = \frac{264Q}{\Delta s} \ldots\ldots (15)$$

An expression for computing the storage coefficient, S, may now be written by equating the second term in the parenthesis in Eq 12 to the value of $\log_{10} \frac{t}{r^2}$ at the zero-drawdown intercept of the straight-line data plot. Thus:

$$\log_{10} \frac{S}{2.25T} = \log_{10}\left(\frac{t}{r^2}\right)_0$$

or

$$S = 2.25T\left(\frac{t}{r^2}\right)_0 \ldots\ldots (16)$$

Converting to USGS units, in which t is expressed in days, r in feet, and T in gallons per day per foot, Eq 16 becomes:

$$S = 0.301T\left(\frac{t}{r^2}\right)_0 \ldots\ldots (17)$$

Figure 10 shows the drawdown test data, taken from Table 1, replotted on semilog paper with s values as ordinates on the arithmetic scale and $\frac{t}{r^2}$ values as abscissas on the logarithmic scale. The plotted points define a straight line starting in the vicinity of Point A, which represents, as it has in previous figures, the location where $\frac{1}{u}$ equals 50. The slope of the straight line, measured over one log cycle, is labeled, and Point B indicates the zero-drawdown intercept of the straight line extended. The value of $\left(\frac{t}{r^2}\right)_0$ at Point B is shown as 1.33×10^{-8}. Appropriate substitution, first in Eq 15 and then in Eq 17, permits computation, as shown in Fig. 10, of the aquifer coefficients of transmissibility and storage. It will be observed that the same answers are obtained by this straight-line solution as by the type curve solution.

Recovery Method

A second important way of analyzing aquifer test data is called the recovery method, which, as the name implies, involves shutting off a pumped well and observing the recovery of water levels in nearby observation wells. In the hypothetical situation previously outlined, the pumped well will be turned off and the recovery of water levels observed in wells No. 1 and 2. Before considering the types of solutions available, it will be desirable to reexamine the hydrograph given in Fig. 5 to see how recovery is measured. Recovery means the difference between the observed water level in the well, sometime after pumping had stopped,

and the level at which the water would have been had pumping continued (see Table 2). It will be noticed on the hydrograph that, 1 day after pumping had stopped, there was a recovery of 6.57 ft, which exactly equaled the drawdown observed 1 day after pumping had begun. A similar comparison could be made anywhere on the recovery and drawdown portions of the hydrograph.

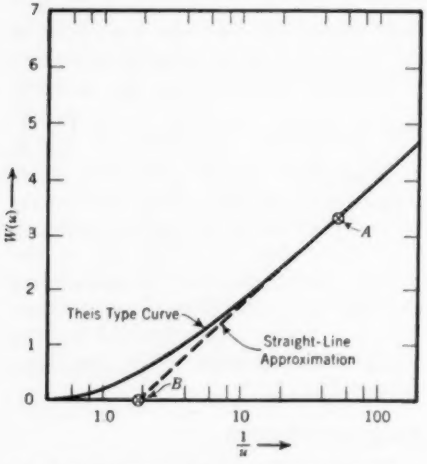

Fig. 14. Straight-Line Approximation (Recovery Data Analysis)

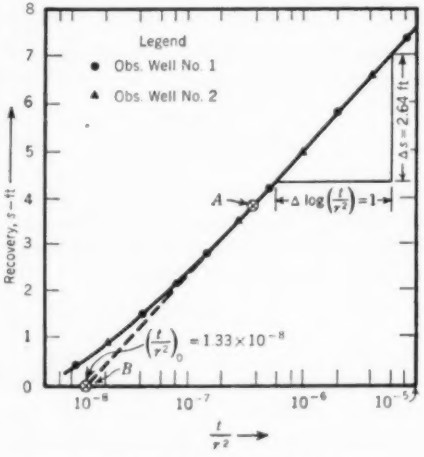

Fig. 15. Plot of Recovery Test Data (Straight-Line Solution)

This curve is the one in Fig. 9 inverted. The equation of the straight-line approximation is, again, $W(u) = \log_e \frac{1}{u} - 0.5772$. *Point* A *is at* $\frac{1}{u} = 50$, *and Point* B, *the zero intercept of the straight line extended, is at* $\frac{1}{u} = 1.78 = e^{0.5772}$.

This agreement between the two types of data is not fortuitous and should suggest that recovery data are merely the reverse of drawdown data or that a recovery test is essentially a negative drawdown test. Stated in another way, it may be imagined that the well pumped during the drawdown test continues to operate during the recovery test, but, at the instant the recovery test is started, an imaginary recharge well is turned on which puts water back into the aquifer at the same location and with a recharge rate equal to the actual pumping rate. Thus, there is no net removal of water from the aquifer; instead, there will be a rise or recovery of water level in any nearby observation well in response to the activity of the imaginary recharge well. It follows, then, that the two types of solutions available for analyzing recovery test data are the same as those already demonstrated for analyzing drawdown data.

As in Fig. 10, the values for Δs *and* $\left(\frac{t}{r^2}\right)_0$ *are found and substituted in Eq 15 and 17. The resulting* T *and* S *values are the same as those obtained by the drawdown method.*

Type Curve Solution

Again a type curve or graphical solution is applicable, and Fig. 11 shows

the Theis type curve replotted for use in the recovery method of testing. It is the same curve as previously shown in Fig. 6, except that it has been inverted to indicate a rising trend comparable to that anticipated for the water levels in the two observation wells. A plot of recovery measurements for the two observation wells, based on data 13, is selected for computation; the match point coordinates are taken from each of the two graphs, and values for the coefficients of transmissibility and storage are computed. It will be observed that the computed coefficients agree with the values already determined by means of the drawdown method.

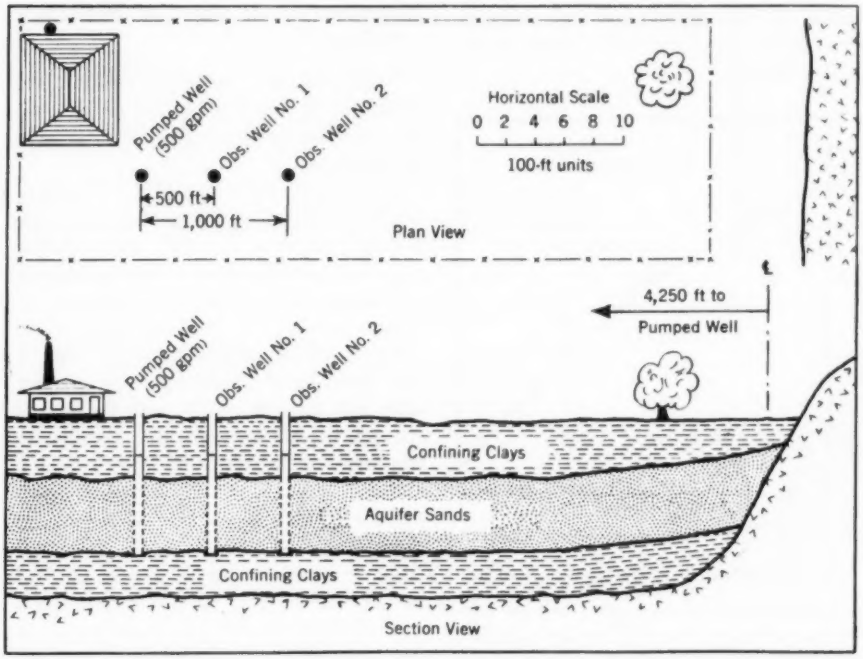

Fig. 16. Hypothetical Test Situation (Aquifer Bounded by Impermeable Barrier)

The situation is the same as in Fig. 4, except that the aquifer is cut off by an impermeable barrier on the right side.

given in Table 2, is shown in Fig. 12, which is likewise merely an upside-down version of the drawdown plot previously seen in Fig. 7. Again it is possible to superpose the data plot on the type curve plot and move it around until a good match position is found, as shown in Fig. 13. A convenient match point, such as the one so labeled in Fig.

Straight-Line Solution

As before, Point *A* in Fig. 11–13 marks the place beyond which the type curve and the data curve become straight lines if replotted on semilog paper. The Theis type curve replotted on such paper (Fig. 14) is identical in form with the curve previously demon-

strated in Fig. 9, except that it is inverted to show a rising trend for the recovery period. Similarly, the recovery data collected from the two observation wells are replotted on semilog paper, as shown in Fig. 15, and a straight line is defined in much the same manner as in the drawdown method. The same abbreviated equations permit computation of the coefficients of transmissibility and storage, the results agreeing with those determined before.

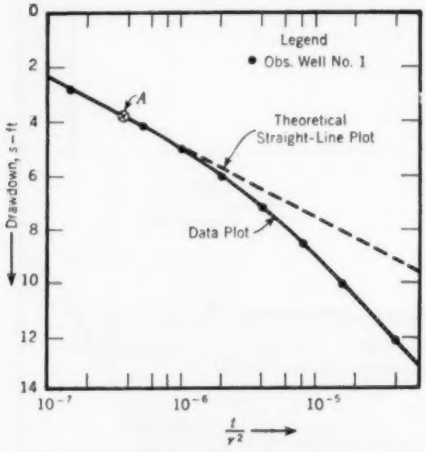

Fig. 17. Effect of Impermeable Barrier

The drawdown data depart from the theoretical straight-line plot because the impermeable barrier limits the extent of the aquifer and increases the drawdown rate.

To summarize the ground covered so far, two basic methods for analyzing aquifer test data—the drawdown method and the recovery method—have each permitted two kinds of solutions, a type curve, or graphical, solution and a straight-line, or approximate, solution. It has been shown how closely the drawdown solutions parallel the recovery solutions. In practice, therefore, it is not necessary to use two kinds of type curves and two kinds of straight-line plots. If it is recognized that a recovery test is essentially the reverse of a drawdown test, one type curve and one straight-line plot will serve equally well for either kind of test data. In fact, both kinds of data can be recorded on the same plot to check their agreement.

Identification of Aquifer Boundary Effects

What happens to the drawdown test data plot if the assumption of an infinite aquifer is unwarranted will now be discussed.

Impermeable-barrier effect. To demonstrate the effect of an impermeable barrier requires another look at the plan and section views of the hypothetical situation, which now appears as shown in Fig. 16. Everything is the same as before (Fig. 4), except that, in the right-hand direction, the aquifer does not extend out to infinity but is cut off by an impermeable barrier in the form of the rising side of a buried valley. This situation is quite common, for example, in the northern and once glaciated parts of the country. Indeed, it often happens that an aquifer is cut off in two directions by such buried-valley walls. It is enough for the purpose of this discussion to view the effects of a single barrier. For convenience, these effects will be demonstrated in the straight-line form of drawdown plot (Fig. 17). The data arrange themselves in the expected manner, as shown previously in Fig. 10, with a curved portion leading into a straight line in the vicinity of Point *A*, the trend being indicated by the broken line. Instead of staying on the straight line, however, the plotted data now curve off below it and eventually define a new straight line having twice

the slope of the original. In other words, drawdown in the observation wells occurs at a faster rate than if the aquifer were of infinite extent. It is possible to take data like these and determine, not only the presence and kind of aquifer boundary, but also its average position with respect to the pumped well. Detailed discussion of to see how the recharge effect of this stream is exhibited on the straight-line form of drawdown plot, as shown in Fig. 19. Once again the plot starts out as expected, with a curved portion leading into a straight line near Point *A*. Instead of continuing on the straight line, as they theoretically should, the plotted data curve away

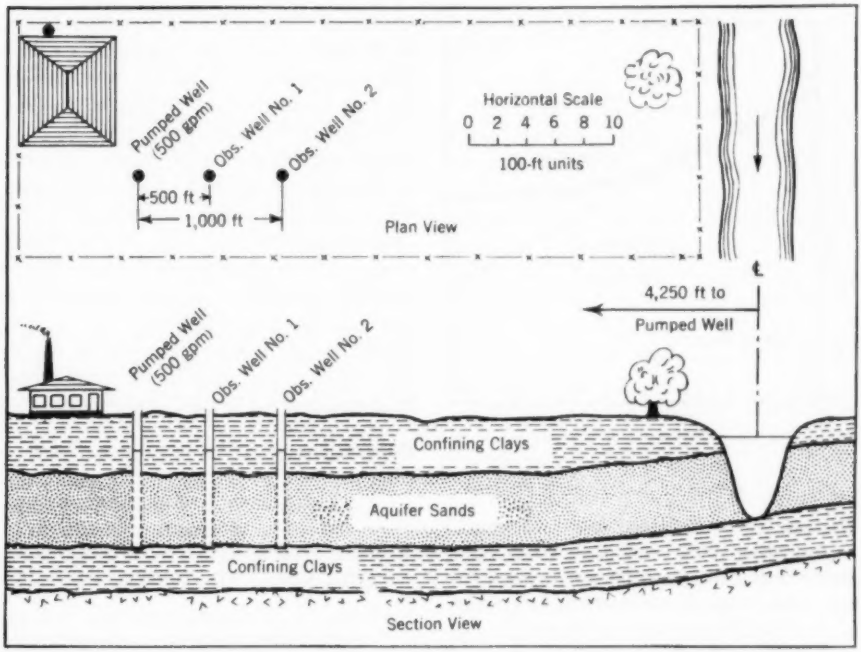

Fig. 18. Hypothetical Test Situation (Aquifer Bounded by Recharging Stream)

The situation is again the same as in Fig. 4, except that the aquifer is bounded on the right by a recharging stream.

these procedures is given by Ferris (*4*) and is beyond the scope of this paper.

Recharge effect of local stream. One other aquifer boundary effect is of interest. Figure 18 shows the same hypothetical situation, except that the aquifer is cut off in the right-hand direction by a recharging stream. This, too, is a situation often found in the field. As before, it will be convenient above it and eventually define a horizontal line. Thus, the rate of drawdown slackens, because of the water contributed to the aquifer by the stream, and gradually approaches a fixed value. It would be possible, from these data, to interpret, not only the presence and nature of the aquifer boundary, but also its location with respect to the pumped well. A complete

discussion of these methods, which might well constitute another paper, has been given by Ferris (*4*).

Conclusion

There are a number of ways in which the hydraulic properties of an aquifer—that is, its coefficients of transmissibility and storage—may be used.

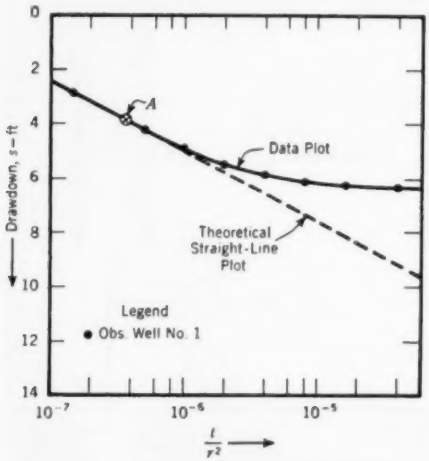

Fig. 19. Effect of Recharging Stream

Instead of following the theoretical straight-line plot, the drawdown data curve shows an upward trend because the recharging stream replenishes the aquifer, reducing the drawdown rate.

Such common problems as the determination of the most desirable spacing between wells in a field, the effects of new wells on existing ones, and the optimum pumping rates and schedules can be worked out once the thickness and extent of an aquifer, its coefficients of transmissibility and storage, and the nature and location of any boundaries present are known. Furthermore, this knowledge is of considerable value in making an overall appraisal of the ground water resources of an area and its potentialities for future water supply development.

It should be reemphasized that this paper has touched on only a few of the methods available today for testing and appraising ground water reservoirs or aquifers. Many of the details and variations of the methods discussed have, of necessity, been ignored or only casually considered. Further information may be found in the references.

It is hoped that this paper has, at least, succeeded in stimulating interest in the fascinating field of ground water study and that some of the basic principles involved have been made intelligible. Those responsible for the development, operation, and maintenance of ground water supplies have an opportunity to obtain a vast amount of scientific information merely through planning and control of well field operations.

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The Problem of Air-Conditioning Water Use

Committee Report

A committee report presented on May 12, 1953, at the Annual Conference, Grand Rapids, Mich., by Frank C. Amsbary Jr., Chairman, Committee A1.C—Water Use in Air Conditioning and Other Refrigeration; Vice-Pres. and Secy., Northern Illinois Water Corp., Champaign, Ill. Other members of the committee were: Elwood L. Bean, L. L. Lewis, and Marsden C. Smith.

THE Committee on Water Use in Air Conditioning and Other Refrigeration was activated by the Board of Directors of the Association to determine the extent and nature of the problems of water utility operation presented by air-conditioning demands. The committee was charged with studying all phases of the problem that appeared to deserve the attention of the industry and recommending means and devices to be used in meeting it.

Both the committee and many individual members of the Association, including committee personnel, have reported on the magnitude of the problem. A number of papers on the subject have been printed in the JOURNAL, as well as in various trade and popular magazines. The committee feels that the water industry is well informed on the problem and that the general public has at least been exposed to it.

In its study, the committee found that water utilities fell into two general classes with respect to the air-conditioning problem: those with a limited source of water supply and those with an entirely adequate source but with other plant facilities that were overloaded or soon would be if some step toward control were not instituted.

For the city with an inadequate source of supply, the committee recommended regulation, particularly if the supply could not be reasonably augmented. In 1950 the committee presented a model ordinance to serve as a guide for those who concluded that regulation best suited the local conditions. Since this model ordinance was published in the December 1950 JOURNAL (*1*), the committee has received numerous favorable reports of its value as a guide from operating water utilities throughout the country.

For the water utility that has an abundant source of supply and an adequate physical plant, the institution of restrictive measures is unnecessary. Such a utility should not restrict the sale of water service for this special type of demand, provided its rates are, or can be, put in line with costs. If they are not, the utility would be promoting a discriminatory situation in which classes of consumers with good load factors would be partly subsidizing those with poor ones.

Demand Charges

To prevent such discrimination and to provide appropriate compensation for a service that has an economically

poor annual load factor, the committee, in its 1950 report (*1*), recommended the institution of demand charges. At that time several manufacturers were attempting to develop demand meters, but none has yet been put on the market. Consequently, it has been necessary to establish other bases for demand charges. For example, in Kansas City, Mo., two rate schedules have been placed in effect. In addition to the usual service charge based upon the size of the meter, the commercial customer * pays these commodity charges:

1. For water purchased by customers having no nonconserved refrigerating or air-conditioning equipment attached to their water systems:

For the first 2,000 cu ft, per 100 cu ft	$0.22
For the next 28,000 cu ft, per 100 cu ft	0.143
For the next 470,000 cu ft, per 100 cu ft	0.099
For all over 500,000 cu ft, per 100 cu ft	0.0825

Provided, however, that the total charge for water delivered to any customer served under this rate through a single meter 1 in. or smaller in size shall not exceed an average of 22 cents per 100 cu ft or the service charge, whichever is greater.

2. For water purchased by customers having nonconserved refrigerating or air-conditioning equipment attached to their water systems:

For the first 2,500 cu ft, for each ton of rated capacity for all such nonconserved refrigerating or air-conditioning equipment for the billing periods corresponding most nearly with the months of June, July, August, and September of each year, per 100 cu ft	$0.16
For the next 2,000 cu ft for such billing periods and for the first 2,000 cu ft for other billing periods, per 100 cu ft	0.22
For the next 28,000 cu ft, per 100 cu ft	0.143
For the next 470,000 cu ft, per 100 cu ft	0.099
For all over 500,000 cu ft, per 100 cu ft	0.0825

It will be noted that the application of Schedule 2 results in progressively higher costs for water service as the air-conditioning capacity increases in tonnage. Melvin P. Hatcher, Director, Kansas City, Mo., Water Dept., states: "It will be readily apparent that the differential is much too low for the smaller air-conditioning installation—up to 15 tons, for instance. We hope some day to be able to establish a more adequate differential in this lower range. . . ."

In Arkansas, the public service commission approved a monthly demand charge of $2.50 per ton of unconserved refrigeration (in effect during the period May–September), in addition to the regular consumption charge. Details are given in a paper by J. R. Pierce (this issue, p. 870).

Manufacturer Cooperation

Another objective of this committee was to acquaint the manufacturers of air-conditioning equipment thoroughly with the problems presented to the water utility and to obtain their cooperation in working out solutions. Through the efforts of L. L. Lewis, Vice-Pres., Carrier Corp., Syracuse, N.Y., a member of this committee, the American Society of Refrigerating Engrs. devoted a

* Those making the study in Kansas City felt at the outset that the residential meter rate was high enough to cover home air conditioning.

session of its 1949 annual meeting to this problem. Papers were presented by two committee members, Elwood L. Bean and Frank C. Amsbary Jr. In addition, a conference was held with representatives of the manufacturers, and problems were discussed in detail. A very satisfactory relationship resulted.

In 1949 the largest air-cooled refrigerating equipment generally available was of 2-ton capacity. Today air-cooled installations of 50-ton capacity are operating satisfactorily. At least one manufacturer will set no limit on the size he will install, economics being the deciding factor. A newly formed ASRE committee, under the chairmanship of Ralph M. Westcott, has been charged with the investigation of water conservation, water application, and water treatment relating to water use in air-conditioning equipment.

Conclusion

The AWWA committee has found that, relative to meeting air-conditioning demands, communities fall into two classes. There are, however, numerous subclasses, distinguished by various factors which are never the same in any two communities. Hence, the solution of the problem must necessarily be a local task rather than one for the committee. Having searched for and reported on enduring principles applicable to the problem, the committee feels that the objectives set for it by the AWWA Board of Directors, as well as the objectives set by the committee for itself, have been accomplished. It is therefore requested that the committee now be placed on inactive status until new developments that demand specific analysis and action arise in the field of water use in air conditioning and other refrigeration.

Reference

1. COMMITTEE REPORT. Regulation of Air Conditioning and Other Refrigeration. *Jour. AWWA*, **42**:1111 (Dec. 1950).

Demand Charge for Air-Conditioning Use in Arkansas

By J. R. Pierce

A paper presented on May 12, 1953, at the Annual Conference, Grand Rapids, Mich., by J. R. Pierce, Vice-Pres. and Gen. Mgr., General Waterworks Corp., Pine Bluff, Ark.

ENGINEERS and water works men are becoming increasingly concerned over the problem of rising water demands created by the use of air conditioning without recirculatory equipment. Although an immediate gain in revenue may result, a thorough analysis indicates that abnormally high demands upon supply, plant, and distribution system facilities can prove very costly to the water consumer and sometimes disastrous to the institution owning the facilities.

The author's firm, searching for a solution that would benefit both its customers and itself, first considered curtailment of service. As the company is in business to sell water and service, however, it was felt that the restrictive approach would be extremely unpopular with the public. An equitable solution was to have the customers who were creating the abnormal demand pay to support the fixed charges essential to provide this type of service. It was therefore decided to establish a demand charge on unconserved air-conditioning water use.

The company assembled the necessary data and filed it with the Arkansas Public Service Commission. (The method by which the demand charge was determined is outlined in the Appendix.) The commission authorized a charge of $2.50 per ton per month during May, June, July, August, and September for air conditioning of 3 tons or more without recirculatory equipment.

The major reason for the action taken by the company was the situation existing in its largest system in Arkansas, which was used as evidence at the public service commission hearing. A company survey found that 10.2 per cent of all water sold was being used for cooling and wasted through the sanitary sewer system. This waste was caused by only 1.2 per cent of the total customers. Based on the growth trend of air-conditioning installations, statistics revealed that in 5 years the connected tonnage would increase from 1,593 to 6,395 and the air-conditioning users would increase to 15 per cent. Assuming that the tonnage connected without recirculatory equipment remained at 23.6 per cent, the peak month cooling-water use would more than double in 5 years. This tremendous increase in demand would require that production and plant facilities be doubled and huge sums spent on strengthening the distribution system. Rate increases to support such an investment would be enormous and would right-

fully be frowned upon by the customers, all of whom would be affected, even though the damage would have been created by only approximately 15 per cent of the total.

It was also pointed out to the commission that the overloaded water system might cause the city to be reclassified downward by the underwriters, resulting in higher insurance premiums. Furthermore, it was shown that the new and improved sewer system might likewise become overloaded in 5 years if the current situation were permitted to continue.

The most favorable evidence presented at the hearing concerned the net savings that the customers could realize by installing conservation equipment. A thorough study was made of all types of recirculatory equipment. From data on first cost, life expectancy, annual maintenance, and operating expense, and assuming a 15-year amortization of the initial investment at 6 per cent, it was found that the customer's savings on the cost of water at prevailing rates (before the demand charge) would pay for the average recirculatory installation in 3 years.

The demand charge was authorized July 1, 1952, to go into effect in 1953. The customers affected were notified long enough in advance so that they would have ample time to purchase and install recirculatory equipment before the effective date of the charge. The company informed these customers of the savings that would accrue to them through the installation of the equipment and recommended its adoption to avoid the demand charge. A relatively small percentage of complaints was received, most of them due to misunderstanding of the results obtainable from the recirculatory equipment.

This peak load problem can in some measure be attributed to overzealous dealers in air-conditioning equipment. Many customers with unconserved air conditioning were ignorant of the saving in water cost provided by recirculatory equipment, as the dealer was afraid that its high first cost would cause him to lose a sale if he recommended it. As a result, the customer would complain to the utility when he began receiving high water bills. Even when he learned the amount of water required, 2–3 gpm per rated ton, and was told of the advantages of conservation, he often preferred to pay the high water bills rather than make the initial expenditure for the recirculatory equipment. The demand charge, in addition to forestalling unreasonable rate increases, helps to encourage the reluctant customer to install conservation equipment.

APPENDIX

Factors in Determination of Demand Charge on Unconserved Air-Conditioning Use

a—Peak monthly unconserved air-conditioning demand.

b—Number of months air conditioning is used (demand charge payable during these months)

c—number of months in which water plant capacity chargeable to air conditioning is *not* used $(12 - b)$

d—Total gallons per year on which demand charge should be paid $(a \times c)$

e—Allocation of (*d*) to months in which demand charge will be collected ($d \div b$)

f—Tons of unconserved air conditioning

g—Allocation of (*e*) to unconserved air-conditioning tonnage ($e \div f$)

h—Total gallons sold in year

i—Total annual operating expense (source of supply, pumping, purification, transmission and distribution, and general)

j—Operating expense per gallon sold ($i \div h$)

k—Sale price of water per gallon (at rate step for usage above normal)

l—Fixed charges per gallon (sale price per gallon less operating expense per gallon, $k - j$)

m—Demand charge per ton per month ($g \times l$)

Revision of Filtering Material Standard

On June 2, 1953, the AWWA Board of Directors approved revisions to the Standard Specifications for Filtering Materials—AWWA B100 which resulted in the following changes:

Sec. 2.1. An addition requires underdrain gravel to be free from undesirable amounts of iron and manganese. Submission of samples for approval of quality is required before shipment.

Sec. 3.1. An addition requires filter sand to be free from undesirable amounts of iron and manganese. Submission of samples for approval of quality is required before shipment.

Table 4. An addition to the footnote requires that the ratio of the 60 to the 10 per cent sizes shall not exceed 1.70 *nor be less than 1.35.* It was further pointed out that, "as the uniformity coefficient of a filter sand approaches unity, the proportion of voids in the sand layer becomes greater, and the ability of the sand to remove finely divided material is reduced."

Effects of Fluoride in North Dakota Water Supplies

By Arthur E. Williamson and Jerome H. Svore

A paper presented on May 15, 1953, at the Annual Conference, Grand Rapids, Mich., by Arthur E. Williamson, Director, Div. of Munic. Eng., and Jerome H. Svore, Chief San. Engr., Environmental Sanitation Services, both of North Dakota Dept. of Health, Bismarck, N.D.

INCREASED interest in the fluoridation of municipal water supplies presented the North Dakota Dept. of Health with the problem of answering a number of questions on fluoridation and its prevention of dental caries. Several of these questions were strictly local in application or pertained only to North Dakota. A review of the literature showed that research on the subject had not progressed far beyond the initial stage of definitely proving that fluorides were beneficial in preventing dental caries. The basic relationships between fluoride content and tooth decay had not been determined, and very little information pertaining to geographical differences was available. Also, the criteria used for comparative purposes did not appear to be ideal and suggested that other comparative analyses should be made.

Accordingly, available data on the effects of fluorides in North Dakota water supplies were analyzed, and the results were published (*1*) in 1951. In an effort to prove or disprove these initial conclusions, a precise, controlled dental survey of school children in North Dakota was carried out in 1952, with the help of the U.S. Public Health Service. The data discussed in this paper are taken from that survey.

Survey Methods

Ten of the larger North Dakota cities were selected for study. The basis of selection was population, fluoride content of the municipal water supply, and continuity of the water source over the past 15 years. A total of 3,220 school children between the ages of six and fourteen, all of whom had used the water supply of a particular city throughout their lifetime, were included in the survey.

The cities were divided into three groups; those with a low or zero fluoride content in the water, those with a medium fluoride content (averaging 0.5 ppm), and those with a high fluoride content (averaging 2.3 ppm). Owing to the small population of the state, it was impossible to carry out the study at closer fluoride intervals. Because of the method used in selecting the children for study, not more than 20 per cent of any school group was likely to qualify. Therefore, only in relatively large cities could a representative sample be obtained.

The actual dental inspections were made by two dental officers from the USPHS. These men were utilized so that a uniform inspection technique would be followed, yielding data that could be compared with statistics obtained from other states at a later date.

TABLE 1

Distribution by Age Group and Fluoride Content

Age	0.0 ppm F		0.5 ppm F		2.3 ppm F	
	Total Children	Avg DMF	Total Children	Avg DMF	Total Children	Avg DMF
6	248	0.71	297	0.44	48	0.04
7	194	1.75	211	1.12	43	0.37
8	200	2.80	215	1.90	36	0.47
9	160	3.45	195	2.37	42	1.31
10	140	4.37	166	2.73	34	1.33
11	112	5.61	128	3.59	29	1.48
12	137	6.30	146	4.37	22	1.95
13	115	8.37	129	5.35	18	2.06
14	74	10.45	67	6.27	13	2.77

Data Obtained

Table 1 shows the distribution of the 3,220 children by age group and fluoride content of the water supply, as well as the average DMF (decayed, missing, and filled teeth) rate. It would have been desirable to have a larger number of children in the high-fluoride category, but the size of the population prevented it.

When the data in Table 1 are plotted arithmetically (Fig. 1), the three curves formed show a definite relationship between the fluoride content and the average DMF per child. The general shape of the curves is of interest in that they are compound curves, with the inflection point at approximately 9 years. Because the two segments of the curve appeared to be logarithmic in nature, the data were plotted on semilog paper (Fig. 2) for further study. This produced straight-line functions made up of two inter-

TABLE 2

*Out-of-State Data**

Age	Grand Rapids, Mich. (0.0 ppm F)		Newburgh, N.Y. (0.1 ppm F)		Aurora, Ill. (1.2 ppm F)	
	Total Children	Avg DMF	Total Children	Avg DMF	Total Children	Avg DMF
6	1,789	0.78		0.48	473	0.28
7	1,806	1.89		1.05	516	0.70
8	1,647	2.94		1.95	469	1.04
9	1,639	3.90		3.11	368	1.52
10	1,626	4.92		4.01	397	2.02
11	1,556	6.41		4.84	383	2.67
12	1,685	8.07		6.36	401	2.95
13	1,668	9.73		7.43	401	3.09
14	1,690	10.94		8.50	433	3.64
15	1,511	12.48			467	4.54
16	1,107	13.50			371	5.19

* Data from Cox and Ast (2) and Arnold, Dean, and Knutson (3). The data were obtained before fluoride was added at Grand Rapids and Newburgh.

secting segments, with the ordinates of the points of interception ranging from 9 to 13 years. The slope of the straight lines in Fig. 2 is indicative of the rate of decay. For purposes of discussion, this slope or rate, in terms of years per DMF, has been defined as a rate of protection. This is the reciprocal of the rate of decay which would be expressed as DMF per year. The curves show that the rate of protection increases with the fluoride content and that there always occurs a

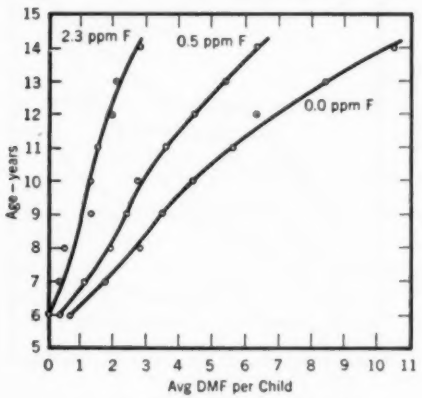

Fig. 1. Fluoride Content and Average DMF

This arithmetical plotting of North Dakota data in Table 1 produces compound curves.

decrease in the rate of protection above a certain age. This observation poses two unanswered questions: why should there be a change in the rate of protection, and why should the age at which this change occurs increase with the fluoride content?

The North Dakota curves were compared with data obtained in other portions of the United States. Information was available in the literature on dental surveys made at Grand Rapids, Mich.; Newburgh, N.Y.; and Aurora, Ill. The fluoride content of these water supplies was known and the method of making the surveys was very similar to that in North Dakota. When plotted on semilog scales, data from these cities (Table 2) produced curves identical with those for North Dakota and falling into proper place in accordance with the fluoride content (Fig. 2). This similarity would indicate

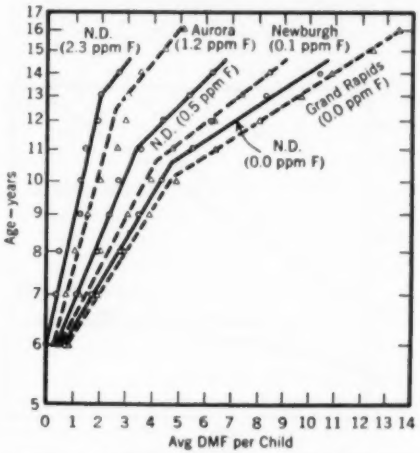

Fig. 2. Fluoride Content and DMF Incidence (Semilog Plot)

When plotted semilogarithmically, the data in Table 1 result in straight-line functions made up of intersecting segments. Data for out-of-state cities (Table 2) fall into place according to fluoride content.

that the shape of the North Dakota curves is generally applicable and is not the result of conditions peculiar to that state.

The natural rate for North Dakota (0-ppm fluoride curve) is somewhat greater than the corresponding rate for Grand Rapids, Mich., possibly owing to a climatic factor, such as the

amount of sunshine. The rate of protection for Newburgh, N.Y., (0.1-ppm fluoride curve) is greater than the natural rate for North Dakota. As similar climatic conditions are to be expected at Grand Rapids and Newburgh, with regard to sunshine, the difference in the rate of protection must be accredited to the small amount of fluoride naturally present in the Newburgh water supply.

The rates of protection indicated by the various curves in Fig. 2 are given

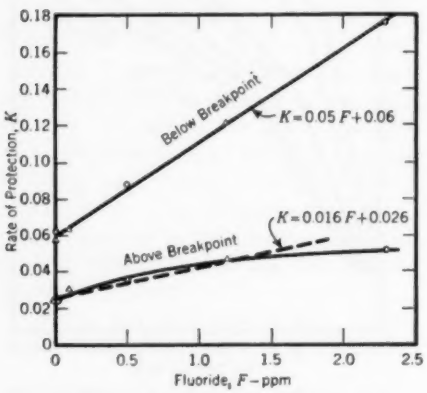

Fig. 3. Rate of Protection

Data on rates of protection (Table 3) are plotted against fluoride content.

in Table 3, together with the corresponding fluoride content. The rates both above and below the breakpoint (point of change of slope) of the curve are shown. When these data are plotted arithmetically, the curve of best fit is a straight line, implying that the relationship of fluoride content to tooth protection is a linear function (Fig. 3). Above the breakpoint of the curves, the linear relationship of rate of protection to fluoride content appears to hold up to concentrations of approximately 1.2 ppm. The data in the present survey are not extensive enough to determine the shape of the curve beyond this point. If the data available are considered an indication of the trend, however, it appears that the curve would level off and approach some asymptotic value in the vicinity of 0.055.

The observation that tooth protection is a directly proportional function of the fluoride content is of consider-

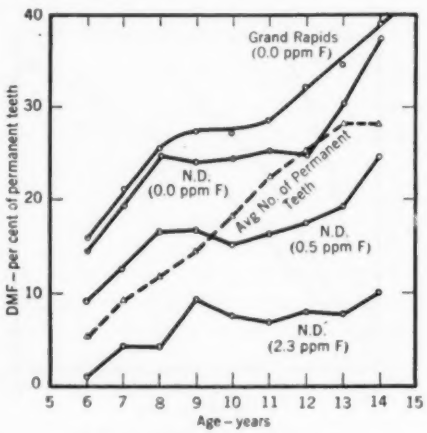

Fig. 4. DMF Percentage

The curves show the average DMF expressed as a percentage of the total number of permanent teeth present at various ages, for different fluoride concentrations.

able interest. It has been the general opinion of previous authors and others active in the field of fluoridation that any fluoride content below 0.5 ppm is of little or no value in the protection of teeth. As the rate of protection appears to be directly proportional to the fluoride content, it must be conceded that 0.1 ppm of fluoride does as much good, proportionately, as 1 ppm and, economically speaking, would

TABLE 3

Rates of Protection

Locality	Fluoride Content *ppm*	Protection Rate, *K*	
		Below Break-point*	Above Break-point*
Grand Rapids, Mich.	0.0	0.057	0.023
North Dakota (low)	0.0	0.062	0.023
Newburgh, N.Y.	0.1	0.063	0.03
North Dakota (medium)	0.5	0.088	0.036
Aurora, Ill.	1.2	0.120	0.046
North Dakota (high)	2.3	0.176	0.051†

* Point at which slope of curve changes.
† Projected value.

bring an equal return on the investment.

To investigate the inflection point of the curves further, various methods of plotting the data were tried. These methods were of no additional value in interpreting the material, except for one study involving a correlation with the average number of teeth present at a given age. When the average DMF values are expressed as a percentage of the possible maximum for that age (Table 4) and are plotted against the corresponding age (Fig. 4), the result is a family of curves whose general shape is quite different from that of previous curves. For the period 8–11 years, the percentage of decay remains fairly constant, with sharply rising percentages of decay both below and above these age limits. Considering the manner in which permanent teeth erupt between the ages of 6 and 13, the general shape of the percentage decay curves indicates that a strong antidecay factor is operating through the 8–11 age period. That this factor is something other than fluoride is borne out by the fact that the flat portion of the curve is very prominent in the 0-ppm fluoride group. Although this flattened portion is present in the curves for the other fluoride groups, the protective effect of the fluoride tends to mask it and to straighten the curve into one horizontal line as the fluoride concentrations increase. At present, no explanation can be given for this apparent decay-resistant period, which is certainly a subject demanding further research.

TABLE 4

Average DMF as Percentage of Total Permanent Teeth Present

Age	Avg No. of Permanent Teeth*	Grand Rapids, Mich. (0.0 ppm F)		North Dakota (Low F)		North Dakota (Medium F)		North Dakota (High F)	
		Avg DMF	Per Cent of Total	Avg DMF	Per Cent of Total	Avg DMF	Per Cent of Total	Avg DMF	Per Cent of Total
6	4.92	0.78	15.8	0.71	14.4	0.44	8.95	0.04	0.81
7	8.95	1.89	21.1	1.73	19.3	1.12	12.5	0.37	4.1
8	11.6	2.94	25.4	2.85	24.6	1.90	16.4	0.47	4.0
9	14.3	3.90	27.3	3.40	23.8	2.37	16.5	1.31	9.2
10	18.1	4.92	27.1	4.37	24.1	2.73	15.1	1.33	7.3
11	22.3	6.41	28.7	5.61	25.1	3.59	16.1	1.48	6.6
12	25.1	8.07	32.1	6.18	24.6	4.37	17.4	1.95	7.8
13	28.0	9.73	34.7	8.50	30.3	5.37	19.1	2.06	7.4
14	28.0	10.94	39.1	10.45	37.3	6.27	22.4	2.77	9.9

* Data from Ast, Finn, and Chase (4).

Conclusions

1. There is a definite relationship between fluoride content and tooth decay in North Dakota. In different school groups having water supplies of different fluoride content, the relationship between age and DMF per child follows the same general type of curve. This curve is compound in nature, with definite inflection points, and appears to be logarithmic.

2. Rate of protection values can be determined for any group using a common water supply, but there will be a lessening of the rate of protection above the ages of 10–13, the age increasing with increasing fluoride content.

3. Data from dental surveys outside North Dakota show the same general change in rates of protection. There is some difference between the natural rates of protection in North Dakota and in other portions of the country, which may be due to climatic factors.

4. The rate of protection is a straight-line function of the fluoride content. Therefore, very low fluoride concentrations do as much good proportionately as the optimum amounts.

5. For comparative purposes, protection rate values should be much better criteria than specific data on DMF per age group.

6. Some factor other than the presence of fluoride retards decay between the ages of 8 and 11.

7. Further investigation should be undertaken to answer two questions posed by observations in the present survey: [1] why does the rate of protection change above a certain age; and [2] what is the apparent anti-decay factor operating between the ages of 8 and 11?

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Defluoridation of Municipal Water Supplies

By F. J. Maier

A paper presented on May 15, 1953, at the Annual Conference, Grand Rapids, Mich., by F. J. Maier, San. Engr. Director, Div. of Dental Public Health, U.S. Public Health Service, Bethesda, Md.

ALTHOUGH an optimum amount of fluoride in water is a valuable means for promoting dental health, excessive concentrations are associated with a hypoplasia of the teeth known as dental fluorosis, the severity depending on the concentration. For example, children who have continuously used water containing 6.0 ppm or more fluoride are, without exception, afflicted with mottled enamel of the permanent teeth. In addition, many of them have gross calcification defects and loss of enamel through attrition. Such defects are permanent and frequently cannot be ameliorated.

Despite the undesirable disfigurement associated with fluorosis, the increased cost of dental care, and the fact that the number of persons using water containing excessive fluoride (over 1.5 ppm) exceeds a total of 1,000,000 in more than 500 communities, only five plants designed specifically for fluoride removal have been built. This failure to utilize an available preventive measure probably is due to the reported high capital and chemical costs and the complexity of the operating procedures in various defluoridation processes.

Ever since the cause of fluorosis and the methods for preventing it became known, a practicable means for reducing excessive amounts of fluoride in water has been sought. To be within the reach of smaller communities, the defluoridation process, it was believed, should make use of equipment comparable to that in conventional treatment plants, should have operating costs within the range of those for softening plants, and should be simple enough to be carried on by local employees with little training.

In selecting a site for demonstrating such processes in a full-scale plant, the U.S. Public Health Service looked for a community having: [1] a water supply containing at least 6.0 ppm fluoride; [2] no realistic prospect of obtaining another, low-fluoride source of water; [3] a population of approximately 2,000 persons, which would yield a minimum significant number in each age group for fluorosis measurements; [4] practically universal metering; [5] a willingness to contribute at least half the capital cost of the plant. The USPHS, because of the fact that the data obtained from such a plant would be of value to other communities throughout the country, would agree to pay the operating cost for the first 10 years.

The Texas Health Dept. suggested that Bartlett, Tex., an agricultural center in Bell and Williamson counties with a population of 1,760, would meet these requirements. Its water is obtained from two wells, 1,000 ft deep, each delivering approximately 220

gpm. A typical analysis is shown in Table 1.

The selection of Bartlett was considered particularly fortunate for demonstration purposes because the town had a water with the highest fluoride content of any public supply in the country, as well as a very high mineral content. If this supply could be treated successfully, the chances were that many others could be. In addition, the city council and public utilities staff were most cooperative and competent.

In order to determine the best process available, an extensive study was made (*1*) and numerous tests were conducted in the USPHS laboratory. In evaluating the published methods for removing fluoride from water, some were found to be worthless, others were impossibly complicated, and most, although they could be used with throw-away media on faucet filters, were too expensive for municipal treatment plants. For the Bartlett plant, the processes available were narrowed down to the use of calcium phosphates, anion-exchange resins, magnesias, or aluminum compounds—materials that can be employed as exchange media and regenerated by chemical treatment.

Calcium Phosphates

It has long been known that bone has an affinity for fluoride. Perhaps the most logical explanation for this reaction involves the anion-exchange properties of apatites. The carbonate radical of the apatite comprising bone, $Ca_9(PO_4)_6 \cdot CaCO_3$, is replaced by fluoride, forming the insoluble fluorapatite (*2*). The caustic soda used in regeneration converts the fluorapatite to hydroxyapatite, with the fluoride removed as soluble sodium fluoride. The hydroxy form then becomes the exchange material, with the hydroxy radical replaced by fluoride.

The use of bone was one of the earliest methods suggested for defluoridating water. The Smiths of Arizona (who share, with Churchill, the discovery that fluoride in water is the cause of fluorosis) suggested the use of degreased, caustic-and-acid-treated bone. This material was not considered for Bartlett because of its high cost—an expenditure of $25,000 would have been required—and because of reports of objections to the taste of water treated by faucet defluoridizers.

TABLE 1

Composition of Bartlett Water

Item	Amount *ppm*
Total solids	2,000
Total alkalinity	400
Phenolphthalein alkalinity	0
Total hardness (as $CaCO_3$)	176
Calcium	41
Magnesium	18
Iron	0.3
Manganese	0.05–
Sodium	560
Silica (SiO_2)	25
Color	0
Turbidity	0
Carbonate	0
Bicarbonate	488
Sulfate	500
Chloride	350
Fluoride	8.0
Nitrate	0.04–
Odor	H_2S
pH	7.8

A similar material, virgin bone black (animal charcoal), is essentially tricalcium phosphate and carbon (*3*). First reports suggested the use of trisodium phosphate and monosodium phosphate as a regenerant. Because this process reduced the capacity of the bed by 12 per cent after the first

regeneration, however, it was not considered for Bartlett. With the development of a caustic soda–carbonic acid regeneration, bone char was selected to replace the original synthetic apatite at another plant under study, at Britton, S.D. This material has been in use for less than a year. Its capacity appears to be approximately 450 grains of fluoride (as F) per cubic foot, while chemical costs are estimated at $50 per million gallons of water treated.*

The principal chemical ingredient of bone, tricalcium phosphate, can be obtained from the reaction between phosphoric acid and lime. If the reaction is carefully controlled, the product is essentially tricalcium phosphate and hydroxyapatite. It can be formed in solution within the mixing basins of conventional treatment (flocculation, settling, and filtration) plants (*4*). Based on pilot plant studies (*5*), the chemical cost of this process at Bartlett would have amounted to $230 per million gallons of water treated. A similar material, trimagnesium phosphate, has been tried but would cost more than tricalcium phosphate because of its lower fluoride removal capacity.

Tricalcium phosphate (synthetic hydroxyapatite) can also be obtained in a porous, relatively insoluble form by controlling the concentrations of the phosphoric acid and lime solutions. It can be fed into water as a powder, followed by settling and filtration (*6*), with the spent material discarded. A more economical method utilizes a larger particle size (20–40 mesh) in a contact filter (*7*). Various improvements in regeneration and extensive laboratory studies resulted in the use of this medium in the first full-scale defluoridation plants, at Climax, Colo., in 1937 (*8*), and at Scooba, Miss., in 1940. Because of prior experience with this material, the USPHS adopted the process at its Britton, S.D., plant in 1948. The water there contains 6.7 ppm fluorides, which was reduced to an equivalent of 1.5 ppm. Both of the earlier plants, at Climax and Scooba, have now been abandoned, while, at Britton, because of excessive attrition losses (42 per cent per year), this medium was replaced with bone char during February 1953.

Ion Exchangers

The removal of fluorides with the various calcium phosphates and aluminum and magnesium compounds involves a combination of ion exchange and sorption. An additional group of defluoridation products depends on ion-exchange properties entirely. A large number of these materials have been developed, many of them patented, and their relative merits have been evaluated (*1*).

A resinous anion exchanger † was at first believed to be the most promising of this group. Later studies showed that its capacity was derived entirely from the precipitated aluminum oxide formed in the column during alum regeneration. This floc so thoroughly restricted the columnar flow as to make the process impracticable. The same company developed a strongly basic anion exchanger ‡ for fluoride removal, intended for use with salt regeneration. A recently published report (*9*) indicates that this material has a fluoride removal capacity of approximately 40 grains per cubic foot of resin when the

* Chemical cost estimates in this paper are based on 1953 prices for the quantities most likely to be used.

† Amberlite IR–4B, a product of Rohm and Haas Co., Philadelphia.

‡ XE–75.

raw water, as at Bartlett, has a fluoride–total anion ratio of 0.0147. The cost of salt alone, based on countercurrent regeneration of 1.0 lb of sodium chloride per cubic foot of resin, would amount to $200 per million gallons of water treated at Bartlett.

The capacity of this exchanger increases rapidly with higher fluoride–total anion ratios, but most high-fluoride waters have a very low ratio. At Britton, for instance, this ratio is 0.0083, which would reduce the capacity to approximately 20 grains per cubic foot.

Proposals have been made to deionize high fluoride waters almost completely and blend the effluent with raw water to produce a final fluoride of approximately 1.0 ppm. Using some of the best exchange materials available (*10*), the cost of chemicals for this process at Bartlett would be approximately $850 per million gallons.

Magnesia

The use of lime was recognized as a means for reducing fluoride in water soon after the cause of fluorosis was discovered (*11*). Later Scott (*12*), in his study of results at lime-softening plants in Ohio, showed that the decrease in fluoride was a function of the magnesium removed. The amount of fluoride removed approximately equaled 7 per cent of the initial fluoride times the square root of the quantity of magnesium removed. Between 45 and 65 ppm magnesium must be removed to realize a 1-ppm reduction in fluoride. Based on this formula, if 1 ppm fluoride is desired in the treated water, 100 ppm magnesium must be removed when the initial fluoride content is 3.3

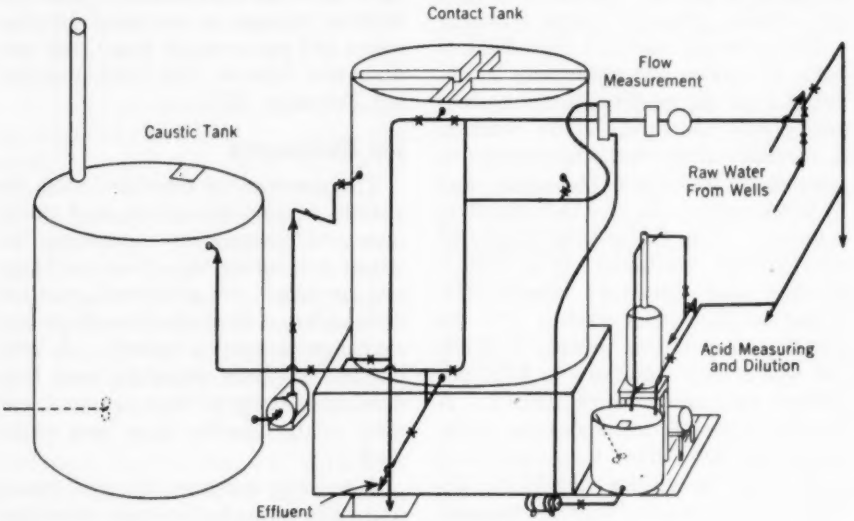

Fig. 1. Bartlett Defluoridation Plant

The steel contact tank is 11 ft in diameter and 11½ ft high. The caustic tank holds 6,000 gal. The installation has a designed flow-through rate of 400 gpm.

ppm. Magnesium concentrations of this magnitude are rare in most high-fluoride waters. When the natural magnesium content is too low for adequate fluoride reduction, dolomitic lime, magnesia (*6*), or magnesium sulfate may be dissolved, converted to magnesium hydroxide, and settled. It has been demonstrated (*13*) that the magnesia becomes partially hydrated, then magnesium fluoride and sodium hydroxide are formed by metathesis, and finally the magnesium fluoride is combined with the magnesia, perhaps forming an oxyfluoride.

Because of the large quantities of chemicals required, this process is adaptable primarily to low-fluoride (3–4 ppm or less) waters requiring softening. Such a plant has been built in Bloomdale, Ohio, where fluorides are reduced from 2.2 to 1.2 ppm, using only the existing magnesium content of the water (*14*). At Bartlett, more than 10 tons of chemicals (carbon dioxide for pre- and postcarbonation, alum, and dolomitic lime), costing approximately $300, would have been required per million gallons of water. In addition, the necessary plant facilities, comprising dissolvers, reaction tanks, and filters, would have cost more than the contact filter type of plant actually adopted. Moreover, the problem of chemical and sludge handling was complicated by the fact that the plant was situated in the center of town.

Aluminum Compounds

Many other materials were tested, including aluminum sulfate, sodium aluminate, zeolites, bauxite, silica gel, sodium silicate, ferric fluoride, and lime (*11*), as well as various absorbent clays and earths (*15*). Except for aluminum sulfate, all of these have been found impracticable for full-scale plants.

Filter alum was recognized as having a relatively high fluoride absorption capacity and was desirable from the standpoint of cost and availability (*16–18*). The capacity can be increased with coagulant aids such as activated silica and clays, but, unfortunately, other anions in the water reduce it. At Bartlett, such interference would have required 900 ppm alum to remove 7 ppm fluoride, at a cost of $190 per million gallons of water for the alum, clay, and silica. Furthermore, this dose of alum would have raised the sulfate content to an even more undesirable level.

Dehydrated aluminum oxide, calcined alumina, and partially hydrated alumina were suggested for use in contact beds. The calcined (activated) alumina had been tried in field tests, in the USPHS laboratory, and at its pilot plant at Bartlett. With Bartlett water, the 10-cu ft pilot plant indicated that the fluoride removal capacity of alumina was 514 grains (as F) per cubic foot. The alumina selected was 28–48 mesh, with a density-in-place of 50 lb per cubic foot, and is commercially available as a desiccant.

Based on pilot plant data, a full-scale plant, containing 500 cu ft of alumina, was designed for Bartlett, assuming a 400-gpm flow-through rate and one regeneration per week during the winter. The plant, housed in a 37 × 24-ft building provided by the city, consists of a steel contact tank, 11 ft in diameter and 11½ ft high, complete with underdrains, wash troughs, and a plastic * caustic distributor; a 6,000-gal

* "Saran," a product of Dow Chemical Co., Midland, Mich.

caustic solution tank with mixer and pump; and acid dilution tanks with metering and proportioning equipment (Fig. 1).

The two 220-gpm well pumps, discharging directly into the contact tank, are controlled automatically by a float switch on the two interconnected, treated-water, ground storage tanks. A float valve on the contact tank actuates a mercury switch connected to the well pumps to prevent overflowing.

fluoride equivalent is attained is illustrated in Table 2. The variations of some of the other ions in the treated water throughout a typical cycle are shown in Fig. 2.

Regeneration of Alumina

The purposes of regeneration are to clean the bed (by backwashing), to remove the accumulated fluorides with a caustic solution, to collect as strong a spent caustic solution as possible for

TABLE 2

Calculation of Equivalent Fluoride

1	2	3	4	5	6	7
Quantity Treated Between Fluoride Readings *1,000 gal*	Cumulative Quantity Treated *1,000 gal*	Fluoride Reading *ppm*	Avg of 2 Readings *ppm*	Col. 1 × Col. 4	Summation of Col. 5	Equivalent Fluoride, $\frac{\text{Col. 6}}{\text{Col. 2}}$ *ppm*
0	0	4.4				
10	10	2.9	3.65	36.5	36.5	3.7
5	15	2.5	2.70	13.5	50.0	3.3
14	29	1.5	2.00	28.0	78.0	2.7
21	50	0.8	1.15	24.2	102.2	2.0
25	75	0.5	0.65	16.3	118.5	1.6
25	100	0.3	0.40	10.0	128.5	1.3
50	150	0.25	0.28	14.0	142.5	0.95
87	237	0.3	0.28	24.4	166.9	0.7
63	300	0.8	0.55	34.7	201.6	0.7
50	350	2.0	1.40	70.0	271.6	0.8
50	400	3.6	2.80	140.0	411.6	1.0

The float switch also actuates the diaphragm valve on the effluent line, which controls the rate of flow and prevents the bed from draining when the pumps stop.

After regeneration, either well pump is started and is thereafter automatically controlled by the level in the storage tanks. When an equivalent of 1.0 ppm fluoride in the treated water is reached, the cycle is stopped and the bed regenerated. The method used to calculate the point at which the 1.0-ppm

the next regeneration, and to remove the residual caustic from the bed with water and dilute acid rinses.

Before regeneration is started, the caustic solution is made up to approximately 1 per cent strength. The concentration of caustic in the returned solution from the previous cycle is determined by titration. The 6,000 gal of return caustic solution contains 125–140 lb of caustic. The difference between this figure and 500 lb is added to the caustic tank.

The acid-handling equipment (Fig. 3) was designed so that no vessel is subjected to pressure and no manual operation involving the acid is required. The sulfuric acid is diluted in two steps—to 15 per cent and then to 0.05*N*. The first step is accomplished by using an aspirator-induced vacuum to transfer 284 lb (18.55 gal) of acid from the shipping drum to the measuring tank. The acid then flows into and is mixed with 194 gal of water in a 252-gal lead-lined tank. During regeneration, this solution is mixed with 61 times its volume of water to produce a 0.05*N* solution.

The bed is first backwashed, primarily to remove accumulated sand, precipitated iron, and oil sludge (from the oil-lubricated well pump bearings). A 30 per cent bed expansion requires 5.7 gpm per square foot, or a maximum of 542 gpm. Approximately 8,000 gal of treated water is used during the 15-min backwashing. Raw water is employed for the remainder of the regeneration.

Caustic solution is then pumped through the bed at a rate of 235 gpm. Even though the void volume of 500 cu ft of medium represents 1,140 gal, approximately 5,500 gal of caustic solution must be passed through the bed before a caustic alkalinity appears in the waste effluent. This is probably due to a chromatographic phenomenon involving progressive adsorption of hydroxyl ions. The volume of the first caustic rinse is chosen so that the largest amount of accumulated fluorides is discarded while maintaining the accompanying caustic strength at a minimum. As shown in Fig. 4, when 2,500 gal of rinse water has been used, most of the

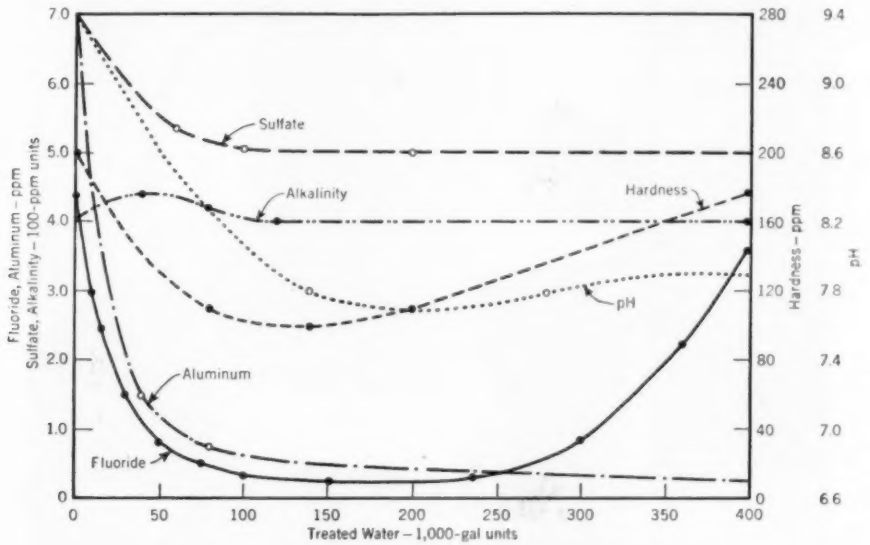

Fig. 2. Concentration of Various Ions During Typical Cycle

Fluoride, aluminum, and sulfate ion concentrations are shown, as well as alkalinity, hardness, and pH.

fluorides have been discarded, while the caustic strength is just beginning to rise. At this point, the caustic return is started and continued until the caustic tank is filled.

A second caustic rinse is used to reduce the alkalinity of the bed to a point at which the further use of raw water alone is uneconomical. The volume (1,500–2,500 gal) is determined by noting where the alkalinity curve begins to become asymptotic. After this point has been reached, acid is used to complete the neutralization of the bed.

The 15 per cent acid previously prepared is diluted with the raw water and distributed over the bed. Generally 12,900 gal of water at 220 gpm is required to produce a 0.05*N* acid solution.

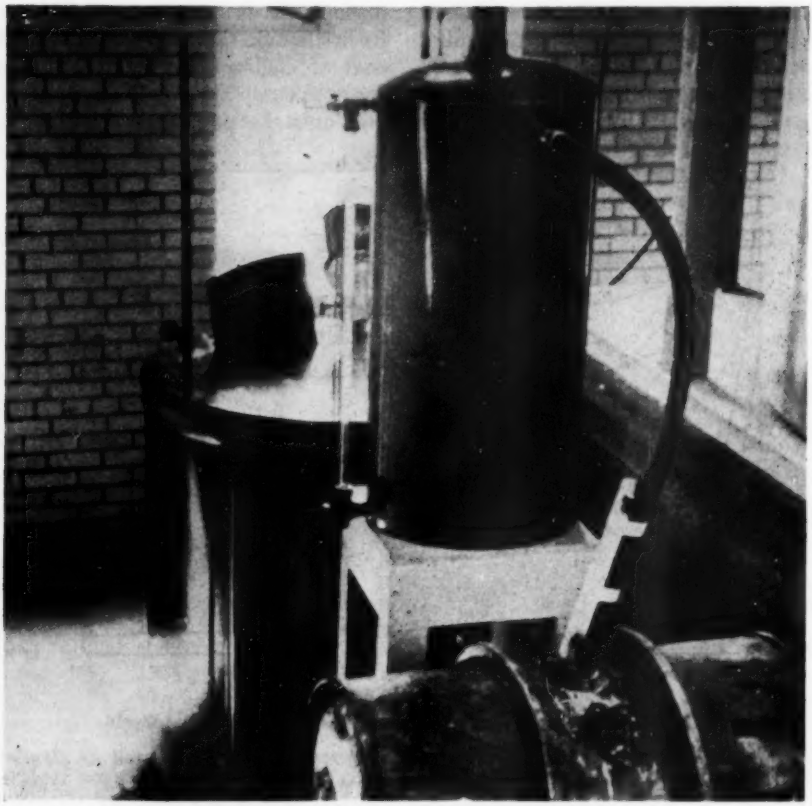

Fig. 3. Sulfuric Acid Dilution Equipment

An aspirator-induced vacuum is used to transfer the acid from the shipping drum (foreground) to the measuring tank (center). The acid is then diluted to 15 per cent in the 252-gal lead-lined tank at the rear.

A final rinse of 20,000 gal is used to lower the initial fluoride reading and reduce the aluminum concentration. The total water required for regeneration amounts to 55,000 gal, of which only 8,000 gal is treated water.

tillations and photometer readings. Changes are being made continually in order to improve the efficiency of regeneration and the fluoride removal capacity of the alumina.

The experience being obtained with

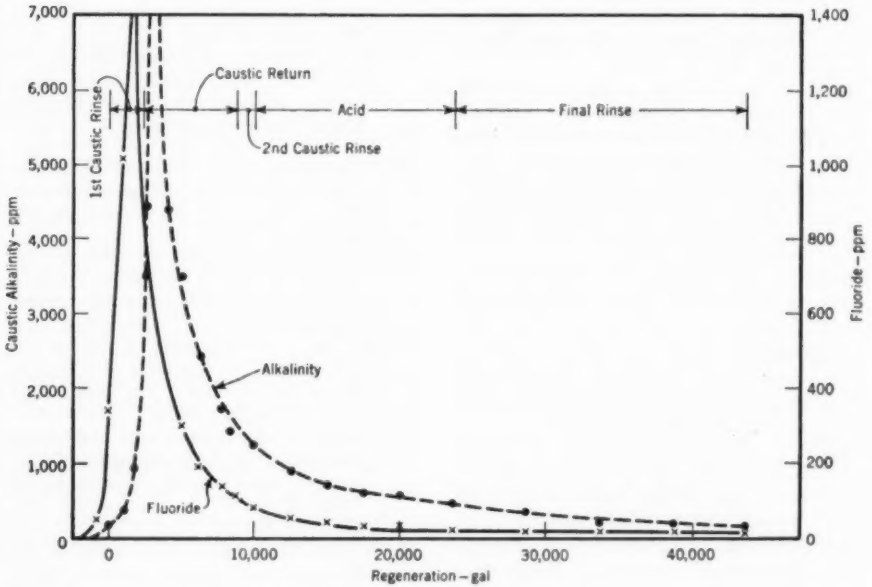

Fig. 4. Progress of Caustic Alkalinity and Fluoride During Regeneration

In the return caustic, the average caustic alkalinity is 3,450 ppm, while the average fluoride is 300 ppm.

Conclusion

Regular operation of the Bartlett plant started Mar. 11, 1952. The cost of chemicals to remove 7.0 ppm fluorides with a 400,000-gal cycle is $52 per million gallons. Equipment costs were $11,360, including installation. The alumina bed cost $4,000 in place. One man, working part time, operates the plant and performs the necessary chemical tests, including fluoride dis-

the various types of defluoridation plants now in operation should provide a basis for adopting this preventive public health measure in the many places where fluorosis is now a problem. Plants have been designed so that local employees can run them successfully. The capital and operating costs are believed to be within the resources of many communities using high-fluoride water.

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A Health Commissioner Looks at Fluoridation

By Albert E. Heustis

A paper presented on May 15, 1953, at the Annual Conference, Grand Rapids, Mich., by Albert E. Heustis, Commissioner, Michigan Dept. of Health, Lansing, Mich.

AS early as 1805 an Italian chemist reported the discovery of fluoride in human teeth and speculated upon its relation to dental disease. In 1892, an English physician, Sir James Browne, stated that the enamel of teeth contained more fluorides than any other part of the body. He attributed the increasing tooth decay he observed to the lack of this element in the diet and suggested that some way be found to reintroduce fluorides into the diet of child-bearing women and children in order to fortify the teeth of the next generation. Unfortunately, this idea was stymied in its infancy, for, in that very year, another eminent person announced that he had discovered the cause of tooth decay, and everyone was more interested in eliminating the cause than in trying to make teeth more resistant.

In the early 1930's after the development of better analytical methods, surveys of the incidence of dental caries were conducted by the U.S. Public Health Service. It was found that in some areas of the country children had fewer cavities than in others. The only factor consistently corresponding with the incidence of caries was the fluoride content of the water: areas with what is now known to be an adequate fluoride level in the water had a lower incidence than those with low-fluoride waters. More surveys were conducted, more studies were made. In every region where the fluoride content of the water was 1 ppm or greater, there were fewer cavities—as much as two-thirds fewer. It was noted, too, that the number of caries rose progressively as the fluoride level fell below 1 ppm, but there seemed to be no additional benefits beyond this concentration. The surveys showed, too, that resistance to dental decay, once established, persisted through adult life. Experiments on animals confirmed the effectiveness of the fluoride ion. The addition of fluoride to the community water supply to obtain the optimum concentration appeared to be desirable, provided it was safe, legal, and feasible.

Safety and Legality

Illness and death statistics were compared for areas with and without natural fluorides in the water. The extensive literature on fluorine was reviewed for cases of acute, low-grade, or chronic poisoning. Absolutely no evidence whatsoever was uncovered that either acute or long-term damage was caused by the prolonged use of fluorides in the amount found effective in the prevention of dental decay. In addition, it was proved that the recommended concentrations provided a very ample safety factor.

In Michigan, the attorney general was asked to rule upon the legal aspects involved. His opinion was that a city starting a fluoridation program would be assuming no more liability than it was already incurring in the operation of a public water supply. He stated that, before liability could be established, it would be necessary for the plaintiff to show negligence on the part of the utility or municipality furnishing the water and to demonstrate that his injuries resulted from such negligence. It was also brought out that Michigan cities had ample legal authority to adjust the fluoride content of the water if they wished to do so. In other states, similar conclusions have been reached.

Feasibility

Next came the question of the feasibility of adding fluorides to the water supply. No technical difficulties were encountered. In general, it was possible to use the type of automatic feeders to which water works men had become accustomed over the years, and the procedure presented no unusual technical problems to trained operators. Hazards in handling the fluoride chemicals were found to be very satisfactorily met with proper mechanical safeguards.

In 1945 a large-scale demonstration was begun at Grand Rapids, Mich., with the local health department, the Dental School of the University of Michigan, the USPHS, and the Michigan Dept. of Health cooperating in the project. Baseline data had been gathered in the preceding year, 1944, when many thousands of school children were examined in Grand Rapids, as well as in Muskegon, Mich., which was to be the control. Both cities obtained their water supplies from Lake Michigan, which is low in fluorides. Several thousand examinations were also made in Aurora, Ill., where the natural-fluoride content in the drinking water is 1.2 ppm. In these studies, it was found that the children in Aurora, Ill., had two-thirds fewer cavities than those in Grand Rapids and Muskegon.

Fluoridation was started at Grand Rapids in January 1945. Checkups were made on several thousand children in Grand Rapids and Muskegon each year. After 5 years of seeing the marked decrease in dental caries at Grand Rapids while its own rate remained at the previous high level, Muskegon tired of being the control and started to fluoridate its own water supply.

Following 8 years of fluoridation, the preliminary analysis of the Grand Rapids data shows that children aged eight and under exhibit the same caries incidence as those in Aurora—that is, children who have received optimally fluoridated water since birth have the same low incidence of caries as do those drinking natural-fluoride water for the same period. These results have been duplicated in other carefully controlled demonstrations at Newburgh, N.Y.; Sheboygan, Wis.; Lewiston, Idaho; Marshall, Tex.; and Evanston, Ill.

Artificial fluoridation of water to improve dental health may therefore be considered safe, legal, feasible, and effective. It is capable of mass application at low per capita cost. The procedure has been endorsed and recommended nationally by the American Dental Assn., the American Medical Assn., the National Research Council, the American Public Health Assn., the Assn. of State and Territorial Health Officers, the American Assn. of Public

Health Dentists, and the USPHS. Its worth was recognized by the Congress of the United States when it approved fluoridation of the water supply of the District of Columbia.

Presentation of Facts

There exists an opportunity for real statesmanship in public health, an opportunity to present the facts clearly and forcibly, so that the people may base their decision upon scientific evidence and not upon emotion or hysteria. A number of previous advances in water treatment, such as coagulation, chlorination, and conditioning, were opposed at the outset, but all of them gradually came to be recognized as being in the public interest. Fluoridation, like water conditioning, goes beyond the traditional aim of furnishing a potable supply free of waterborne bacterial diseases. In common with softening, fluoridation involves an adjustment of the chemical constituents of the water in the interest of the consumer. People in many parts of the country are already receiving this protection. The drinking water is being adjusted by trained technicians—water works operators—working as a part of the public health team, under medical and dental guidance and responsibility, and under laboratory and engineering control.

Disability is disability, regardless of its cause. If it is within the power of those who serve the public to overcome a disability that affects almost everyone, the people should be given the facts. If fluoridation is in the public interest, it is the concern of public health and water officials, who, as statesmen, must, in a forthright fashion, analyze the arguments of those who are opposed to the procedure. It is necessary to combat baseless fear with knowledge and to see that comparisons are valid and proper. It is equally necessary to recognize and accept such opposition arguments as have merit. Quotations must be cited in context, and the real issue must not be clouded. Above all, it is essential to consider the background, knowledge, and experience of those who wish to be heard on the subject.

It must be kept in mind that dental caries, in addition to being a bacterial disease, is, at least in part, a deficiency disease as well. It is a condition affecting nearly everyone, and there is simply not enough dental manpower to treat it, even if all could afford it. Prevention along with treatment has played a tremendous part in the development of the present-day health status. Being partially a deficiency disease, dental caries can be prevented to a great extent by making up the deficiency through adjusting the fluoride content of the drinking water so that resistant dental enamel will be developed.

Everyone must understand that there is scientific proof that the fluoride ion acts the same way in the prevention of dental cavities whether it is put into the water by nature or by man. It must also be understood that fluorides are a normal constituent of teeth.

It should be emphasized that fluoride, in the amount recommended, is perfectly safe. At 1 ppm, it would take well over 1,000 8-oz glasses of water, all consumed at the same time, to supply enough fluoride for a person to feel sick. In order to produce water with 1 ppm of fluoride, a machine is designed to feed approximately 20 lb of sodium fluoride into each million

gallons of water. It would take 4 tons of the material per million gallons of water to get enough fluoride in a glassful of water even to make one sick. Illness and death rates in areas with natural-fluoride and nonfluoride waters are found to be identical, if the figures are correctly quoted and if true comparisons are made.

Conclusion

The supervision and control required for adjusting the fluoride content of water is easy and inexpensive to supply. It would be much more difficult and costly to provide this supervision and control for untried methods that have been suggested. Supervision and control, are, of course, the key to the whole program.

Competent operation of the fluoridation process is assured in Michigan, as in many other states, through supervision and control by the state health department and through the certification of operators. In this way, responsibility can be fixed and continuity of service assured. Educational projects in which the state health department and the local AWWA section cooperate are very effective devices for making available to water works men the knowledge they require to perform their jobs with credit both to themselves and to their communities.

The Michigan Dept. of Health recommends supplementation of fluoride-deficient water supplies, with medical and dental direction, by trained technicians working under laboratory and engineering control. Here truly the water works operator once again takes his place in the small band of dedicated people whose job it is not only to prevent disease but also to develop the greatest possible degree of health.

Revision of Gate Valve Specifications

The AWWA Board of Directors has approved the addition of a new subsection in Sec. 6—*Valve Ends* of the Tentative Standard Specifications for Gate Valves for Ordinary Water Works Service—AWWA C500–52T. The addition reads:

Sec. 6.3—Ends for Mechanical-Joint Pipe

When a valve is to be connected to mechanical-joint pipe, the bell dimensions shall conform to Table 11.1 of ASA A21.11 (American Standard Specifications for a Mechanical Joint for Cast Iron Pressure Pipe and Fittings).

Census of Fluoridation in the United States and Canada, 1952

Committee Report

A committee report presented on May 11, 1953, by R. S. Phillips, Supt. of Plants and Chief San. Engr., Water Dept., Charlotte, N.C. The other members of Committee E5.10—Fluoridation Materials and Methods were: O. J. Muegge (Chairman), C. R. Cox, H. A. Faber, M. E. Flentje, W. L. Harris, R. W. Ockershausen, L. A. Smith, D. B. Williams, and J. C. Zufelt.

THE addition of fluoride compounds to water supplies for dental-caries control received increasing acceptance in Canada and the United States during 1952. This is the one overriding fact gained from the results of a questionnaire sent by the committee to, and answered by, all 48 state sanitary engineers plus the District of Columbia and the province of Ontario, Canada.

By the end of 1952, in the United States, 12,590,292 persons were drinking fluoridated water, in addition to those whose water supplies already contained natural fluorides. All states but five had fluoridation plants by the end of the year. A summary of data gathered by the committee for the period 1945–52, given in Table 1, illustrates the rapid growth of fluoridation in recent years. In 1952 the number of plants more than doubled while the population served nearly tripled. At the end of the year, 13 per cent of the urban population of the United States was being supplied with fluoridated water.

The upward trend is continuing. The U.S. Public Health Service estimates that, as of May 15, 1953, 14,350,000 people in 777 communities, served by 409 water works, were receiving fluoridated water. In addition, 357 communities, with a total population of 15,800,000, had approved fluoridation but had not yet started it by that date.

Two fluoridation projects were reported discontinued in 1952. Mount Dora, Fla., shut down its plant in August 1952 after an unfavorable vote by its citizens. Kennewick, Wash., discontinued operations pending the purchase and installation of new equipment.

In spite of the continued overall gains shown each year, it is reported that some water works personnel are against fluoridation. Other groups also continue to make their opposition heard. This policy problem is outside the scope of the committee's activity.

Table 2 lists those fluoridation plants in the United States and Canada for which sufficient data were available. The names of cities and towns supplied with fluoridated water, population served, dates and types of installation, and fluoride concentrations maintained are given. Only plants installed and in operation as of Dec. 31, 1952, are included. Fifty-one plants, serving an additional 1,205,405 persons and known to have been installed or placed in operation during January, February, and March 1953, are not included.

In 1952 Wisconsin, with 83 separate fluoridation plants, led all other states in number of installations. It had as many as the next four states combined (Michigan, 27; Minnesota, 27; Kentucky, 15; and Indiana, 14). The District of Columbia and Maryland, with large fluoridation plants that began operations in 1952, brought these areas into the forefront, based on the percentage of urban population being served fluoridated water. Table 3 shows the states having the greatest number of fluoridation systems at the end of 1952.

Fluoridation Chemicals

Five chemicals are reported in use for fluoridating water supplies: sodium fluoride, sodium silicofluoride, hydrofluosilicic acid, hydrofluoric acid, and ammonium silicofluoride. Sodium silicofluoride is now the most widely employed, with additional plants reported to be changing from sodium fluoride, the second most frequently used chemical. Hydrofluosilicic acid continues to gain some ground. Hydrofluoric acid and ammonium silicofluoride are reported in use at only one installation each.

As a result of a cooperative effort by the AWWA, the USPHS, and the General Chemical Div., Allied Chemical and Dye Corp., New York, bulk shipment of fluoride salts is now permitted in covered hopper-bottom cars carrying a minimum of 50,000 lb. The storage of bulk fluorides appears to warrant additional study, however, as compaction and erratic feed results were experienced in one large installation. Manufacturers are reported to be working on the problem. Until recently experience with bulk storage of fluorides was lacking.

Fluoridation Equipment

Information was furnished on the type of feeding equipment in 184 new plants installed during 1952. Dry-feed equipment accounted for 125 of the 184 installations. More than half (104) of all new installations were designed for use with sodium silicofluoride. Summary and comparative data on chemicals and equipment are shown in Table 4.

Reported costs of complete fluoridation installations ranged from $300 to $12,000 for solution-feed types and from $750 to $90,000 for dry-feed equipment. In considering the figures in Table 5, it should be kept in mind that the size of the population to be served is only one factor in the cost of an installation. Many other factors are involved, including the local requirements of the particular water supply.

Owing to a recent 25 per cent increase in sulfur prices, hydrofluoric acid and sodium fluoride made from hydrofluoric acid are reported to be advancing in price. Whether the price of sodium silicofluoride, a phosphate industry byproduct, will advance or not, is not known. The sulfuric acid used in digesting phosphate rock will certainly cost the producer more money.

Operating Difficulties

The committee's questionnaire attempted to find out whether the occasionally reported difficulties in feeding fluoride chemicals were being experienced generally throughout the country. Only 20 of the 43 states having fluoridation systems reported chemical or feeding difficulties. Table 6 summarizes the replies.

Clogging of the discharge line was reported in some instances to have been caused by the reaction of water hardness with sodium fluoride solutions. Whether arching and packing in the hoppers of chemical feeders were due to the chemical used or to the type of equipment employed was not specified in the answers to the questionnaire. Several replies mentioned moisture in the chemical as a cause of arching and packing.

One fluoride producer is reported reluctant to bid for municipal business because his product will not feed properly in some types of equipment and because routine price quotations may not be applicable to the specific needs of the city installation. It would appear that the future work of the committee might profitably include a study of this problem by coordinating all information available from municipalities, equipment manufacturers, and chemical producers.

Fluoride Concentrations

The minimum concentration of fluoride in water considered effective for dental-caries control varies from state to state, as would be expected. All states in the New England, Middle Atlantic and East North Central regions regard a minimum of 1.0 ppm as effective. The West North Central states, Kentucky, and some of the Rocky Mountain states consider 1.0–1.2 ppm a desirable minimum. In the South, Southwest and Pacific Coast regions, fluoride concentrations ranging from 0.4 to 1.0 ppm are considered effective.

Only five municipal defluoridation plants, serving a total of 5,000 people, are reported in operation in the United States. Only seventeen states report standards recommending the installation of defluoridation equipment if specified concentrations of fluoride are present in the water. The concentration at which defluoridation is recommended varies widely, ranging from 1.0 to 3.0 ppm. Geographic location does not appear to be a factor. Data on fluoridation and defluoridation standards, together with the number of defluoridation plants in operation, are shown in Table 7.

TABLE 1

Summary of Fluoridation Plant Census, 1945–52

	United States				Canada	
Year	States With Plants	No. of Water Systems	Communities Served	Total Population Served*	No. of Water Systems	Total Population Served
1945	3	3	3	209,447	1	40,000
1946	7	9	9	301,520	1	40,000
1947	9	11	11	388,146	1	40,000
1948	9	13	18	493,406	1	40,000
1949	11	27	33	777,033	1	40,000
1950	16	62	78	1,384,153	1	50,000
1951	37	172	240	4,410,079	1	50,000
1952	43†	354	447	12,590,292	5	128,000

* Based on 1950 census.
† Plus District of Columbia.

TABLE 2—*Fluoridation Plants in the United States and Canada, Dec. 31, 1952*

Locations Served	Population Served in 1950	Chemical Used			F Residual Maintained *ppm*	Date Installed
		NaF	Na_2SiF_6	H_2SiF_6		
Alabama						
Sheffield	10,767		D		0.75–1.0	12/52
Tuscaloosa	52,734		D		0.75–1.0	6/51
Holt						
Northport						
Arizona						
None						
Arkansas						
Jonesboro	16,310		D		1.0	10/51
Nettleton	1,382					
Little Rock	102,213		D		1.0	4/51
Cammack Village	987					
N. Little Rock	44,097					
Springdale	5,835		D		1.0	11/52
Walnut Ridge	3,106	S			1.0	1/52
California						
Antioch	11,051		D		1.0	8/52
Morgan Hill	1,627	S			1.0–1.2	2/52
Rio Vista	1,831		D		1.0–1.2	10/51
San Diego	334,387		D		1.0–1.2	12/52
San Francisco	775,357		D		0.95	8/52
Colorado						
Grand Junction	14,504		D		0.9	6/51
Johnstown	900	S				8/52
Lafayette	2,090	S				11/52
Connecticut						
Cromwell Fire Dist.	2,500	St			1.0	6/51
Mansfield State Tr. School	1,700	S			1.0	11/50
New Britain	78,000	D			1.0	12/50
Southbury State Tr. School	1,800	S			1.0	4/45
Delaware						
Newark	6,731	S			1.0–1.2	10/50
District of Columbia†	800,000		D		1.0–1.2	6/52
Florida						
Clewiston (P)	2,499		D		0.6–1.1	10/51
Gainesville	26,861	D			0.6–1.1	10/49
Miami	249,276		D			4/52
Coral Gables	19,837					
Miami Beach	46,282					
Miami Shores	5,108					

* Key to symbols and abbreviations in table: P—privately owned utility; S.D.—sanitary district; I.D.—irrigation district; D—dry-feed equipment; S—solution- or slurry-feed equipment (slurry feed is applicable only to sodium silicofluoride installations); St—saturator type feeder.

† Also supplies cities in Virginia (239,000 population).

TABLE 2 (*contd.*)—*Fluoridation Plants in the United States and Canada, Dec. 31, 1952*

Locations Served	Population Served in 1950	Chemical Used			F Residual Maintained *ppm*	Date Installed
		NaF	Na_2SiF_6	H_2SiF_6		
Miami, Fla. (*contd.*)						
Miami Shores Village	5,086					
South Miami	4,809					
West Miami	4,043					
Naples	1,465	D			0.6–1.1	10/51
Georgia						
Athens	28,180	D			0.7	1951
DeKalb County	110,000		D		0.7	1951
Gainesville	10,750	D				6/52
Monroe	3,000	D				8/52
Rome	26,500					6/52
Rossville†	10,000				0.8–1.0	9/52
Idaho						
Bonner's Ferry	1,776		D		1.25	3/52
Coeur d'Alene (P)	12,198		D		1.1	1/52
Lewiston	12,985	D			1.0	6/47
Lewiston Orchards I.D.	5,000		D		1.0	6/52
McCall	1,173		D		1.0	11/52
Preston	4,045		D		1.0	1/52
Salmon	2,648		D		1.0	9/52
Sandpoint	4,265		D		1.25	3/52
Kootenai	199					
Ponderay	248					
Illinois						
Assumption	1,466	S			1.0	9/51
Carbondale	10,921		D		1.0	7/52
Carlyle	2,669		D		1.0	6/52
Casey	2,734	S			1.0	8/52
Chester	5,339		D		1.0	12/51
Child Home Normal	200		S		1.0	9/52
Evanston	73,641	D			1.0	2/47
Orion	829	S			1.0	9/52
Park Forest (P)	8,138	D			1.0	12/52
Waukegan	38,946		D		1.0	3/52
Winnetka	12,105		D		1.0	12/52
Indiana						
Batesville	3,194	S			1.0	3/52
Oldenburg	591					
Bedford	12,562		D			1/52
Oolitic	1,125					
Bloomfield (P)	2,086		D		1.0	9/52
Columbus	18,370		D		1.0	12/51
Fort Wayne	133,607		D		1.0	7/51
Huntingburg	4,057		D		1.0	8/51
Indianapolis (P)	439,137	D			1.0	8/51

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† Supplied by Chattanooga, Tenn.

TABLE 2 (*contd.*)—*Fluoridation Plants in the United States and Canada, Dec. 31, 1952*

Locations Served	Population Served in 1950	Chemical Used			F Residual Maintained *ppm*	Date Installed
		NaF	Na_2SiF_6	H_2SiF_6		
Indianapolis, Ind. (*contd.*)						
Beech Grove						
Ben Davis						
Mars Hill						
Southport						
Woodruff Pl.						
Kokomo (P)	38,672		D		1.0	7/52
Lyons	695	S			1.0	4/52
Marion	30,081		D		1.0	9/52
Michigan City	28,395		D		1.0	3/52
Tell City	5,735	D			1.0	5/52
Valparaiso	12,028	D			1.0	10/52
Zionsville	1,536	S			1.0	11/51
Iowa						
Cedar Rapids	72,296	D			1.2	4/52
Clarinda	5,086	D			1.2	9/52
Davenport	74,459	D			1.2	7/52
Bettendorf	5,132					
Dubuque	49,671	D			1.2	10/51
Fairfield	7,299	D			1.2	11/52
Hartley	1,611	S			1.2	8/52
Indianola	5,145	D			1.2	12/52
Manchester	3,987	S			1.2	12/52
Waukon	3,158	S			1.2	10/51
Kansas						
Coffeyville	22,000		D		1.0	10/52
South Coffeyville						
Colony	397	S			1.0	12/52
El Dorado	11,878		D		1.0	9/52
Fort Scott	10,447		D		1.0	8/52
Garnett	2,659			S	1.0	6/52
Hays	8,551		D		1.0	8/52
Horton	2,900			S	1.0	1951
Iola	7,920			S	1.0	12/52
Gas City						
La Harpe						
Junction City	13,682		D		1.0	1/52
Minneapolis	1,809			S	1.0	8/52
Ottawa	10,000	S			1.0	1946
Seneca	1,945			S	1.0	8/52
Kentucky						
Ashland	39,800		D		1.2	11/52
Central City	4,110		D		1.2	3/52
Cynthiana	4,832		D		1.2	3/52
Elizabethtown	5,800		D		1.2	7/51
Franklin	4,343		D		1.2	5/52
Glasgow	7,025		D		1.2	2/52

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		NaF	Na_2SiF_6	H_2SiF_6		
Kentucky (*contd.*)						
Greensburg	1,000			S	1.2	4/51
Hopkinsville	12,500	D			1.2	8/51
Lancaster	2,350		D		1.2	12/52
Louisville	370,000		D		1.2	8/51
Martin	1,170	S			1.2	4/52
Mayfield	12,000		D		1.2	9/52
Maysville (P)	8,700		D		1.2	4/51
Paintsville	4,307			S	1.2	4/52
Versailles	2,760		D		1.2	9/52
Louisiana						
St. Martinville	4,614	D			1.0	4/52
Maine						
Norway	3,000		D		1.0	10/52
Maryland						
Baltimore Met. Dist.	1,200,000			S	1.0	11/52
Bel Air (P)	3,000	S			1.0	11/52
Hagerstown	36,260		D		1.0	12/51
Cavetown	300					
Funkstown	879					
Halfway	2,153					
Roxbury & Penal Farm	700					
Security	300					
Smithsburg	641					
Williamsport	1,886					
Washington Suburban S.D.	310,000		D		1.0	6/52
Massachusetts						
Belchertown State School	1,283	S			1.0	12/46
Concord	2,299	S			1.0	8/52
Kalmia Woods						
Danvers	18,500		D		1.1	5/50
Middletown						
Salem	70,764		D		0.9	12/52
Beverly						
Templeton	4,100		D		1.0	1/51
Wrentham State School	1,968	S			1.0	12/46
Michigan						
Algonac	2,607		D		1.0	9/49
Pearl Harbor	400					
Ann Arbor	47,279		D		1.0	12/51
Battle Creek	48,469	D			1.0	4/51
Benton Harbor	18,769	D			1.0	9/51
Buchanan	5,224	S			1.0	10/52
Grand Haven	9,536			S	1.0	6/52
Grand Rapids	175,647	D			1.0	1/45

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		NaF	Na_2SiF_6	H_2SiF_6		
Grand Rapids, Mich. (*contd.*)						
Cascadia	600					
E. Leonard Heights	400					
Irvindale	1,000					
Grosse Pte. Farms	9,365		D		1.0	5/51
Grosse Pte. Village	6,283					
Hastings	6,060		D		1.0	1/51
Highland Park	46,393		D		1.0	9/52
Jackson	50,904		D		1.0	8/51
Kalamazoo	57,704	D			1.0	8/51
Lake Odessa	1,596			S	1.0	8/52
Ludington	9,066	S			1.0	12/49
Marquette	17,345		D		1.0	9/51
Marysville	2,534		D		1.0	4/52
Midland	14,202		D		1.0	1/46
Monroe	21,467		D		1.0	12/51
Mt. Clemens	16,815		D		1.0	3/51
Harrison Twp.	1,000					
Muskegon	48,047	D			1.0	7/51
North Muskegon	1,694					
Negaunee	6,472		D		1.0	11/51
Saginaw	92,352		D		1.0	5/51
South Haven	5,629		D		1.0	2/52
Traverse City	16,974		D		1.0	5/52
Wyandotte	36,666		D		1.0	1/51
Minnesota						
Appleton	2,256				1.2	1952
Arlington	1,313				1.2	1952
Austin	23,100				1.2	1952
Benson	3,398	S			1.2	12/51
Circle Pines	339				1.2	1952
Cloquet	7,685				1.2	1952
Ely	5,474				1.2	1952
Fairmont	8,193		D		1.2	4/51
Fergus Falls	12,917		D		1.2	4/51
Granite Falls	2,511				1.2	1952
Hallock	1,552		D		1.2	12/51
Hutchinson	4,690				1.2	1952
International Falls	6,269				1.2	1952
Madison	2,303				1.2	1952
Mapelton	1,083				1.2	1952
Montevideo	5,459				1.2	1952
Mora	2,018				1.2	1952
Morris	3,811				1.2	1952
New York Mills	977				1.2	1952
Okabena	236				1.2	1952
Red Lake Falls	1,733	S			1.2	4/51
Rush City	1,175				1.2	1952
St. Paul	311,349				1.2	1952

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		NaF	Na_2SiF_6	H_2SiF_6		
Minnesota (*contd.*)						
Scanlon	572				1.2	1952
S. International Falls	1,840				1.2	1952
Staples	2,782				1.2	1952
Thief River Falls	6,926		D		1.2	12/51
West Concord	770	S			1.2	12/51
West St. Paul	7,955				1.2	1952
Winnebago	2,127	S			1.2	4/51
Mississippi						
Columbus	17,170		D		1.0	8/51
Forest	2,875		D		1.0	2/52
Missouri						
None						
Montana						
Chinook	2,250		D		1.0	3/52
Roundup	2,862	D			1.0	2/52
Nebraska						
Beatrice	11,813		D		1.2	4/51
Fairbury	6,395		D		1.2	3/52
Nebraska City	6,872		D		1.2	10/52
Superior	3,227	D			1.2	7/51
Nevada						
None						
New Hampshire						
Concord	25,000		D		1.0	5/52
New Jersey						
Morristown	25,000	S & D			1.0–1.2	1950
Hanover Twp.						
Morris Plains						
Morris Twp.						
Rahway	21,290		D		1.0–1.2	6/52
New Mexico						
None						
New York						
Carle Place†	3,000				1.0	3/52
Gloversville	23,600		D		1.1	4/52
Hoosick Falls	4,300		D		1.0	9/52
New Rochelle	100.000	D			1.0	10/51
Ardsley						
Bronxville						

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† Uses ammonium silicofluoride with solution feeder.

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		NaF	Na_2SiF_6	H_2SiF_6		
New Rochelle, N.Y. (*contd.*)						
East Chester						
North Pelham						
Pelham						
Pelham Manor						
Tuckahoe						
Newburg	32,000	D			1.0	5/45
Olean	25,000		S		1.0–1.2	11/51
Poughkeepsie	41,000		D		1.0	10/52
Rochester	332,500		D		1.1	9/52
Westfield	3,700		D		1.0	2/52
North Carolina						
Charlotte	145,000		D		0.6–1.1	4/49
Pineville						
Concord	16,500		D		0.9–1.1	7/52
Dunn	9,000		D		0.9–1.1	12/52
Fayetteville	40,000		D		0.9–1.1	10/52
Greensboro	95,000		D		0.9–1.1	10/52
Lenoir	7,450		D		0.9–1.1	11/52
Roanoke Rapids	8,000		D		0.9–1.1	11/52
Rockingham	4,500	S			0.9–1.1	12/52
Rocky Mount	36,000		D		0.9–1.1	12/52
Salisbury	26,500	D			0.9–1.1	7/52
Southern Pines	6,500		D		0.9–1.1	11/52
Winston-Salem	100,000		D		0.8–1.2	10/51
North Dakota						
Dickinson	7,469			S	1.0	7/52
Fargo	38,256		D		1.0	5/52
Mandan	7,298	D			1.1	10/52
Northwood	1,168	S			1.2	11/51
Ohio						
Avon Lake	4,500			S	1.0	8/51
Canton	125,000			S	1.0	2/52
Glendale	2,400	S			1.0	12/52
Lisbon	3,300			S	1.0	8/51
Mahoning S.D.	190,000		D		1.0	9/52
McDonald						
Niles						
Youngstown						
Martins Ferry	18,000		D		1.0	8/52
Bridgeport						
Brookside						
Westerville	4,200	S			1.0	6/51
Oklahoma						
Bartlesville	19,228		D		1.0–1.2	7/52
Guthrie	10,113		D		1.0–1.2	11/52
Nowata	3,965		D		1.2	8/51

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TABLE 2 (*contd.*)—*Fluoridation Plants in the United States and Canada, Dec. 31, 1952*

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		NaF	Na_2SiF_6	H_2SiF_6		
Oregon						
Astoria	12,331		D			12/52
Corvallis	17,496		D		1.0	6/52
Florence	1,026	S			1.0	6/52
Forest Grove	4,343		D		1.0	10/52
Gearhart	568	S			1.0	7/51
Pendleton	12,291		D		1.0	12/52
Pennsylvania						
Brookville	4,600	D			1.2	9/51
Easton	55,000					
Lehigh Plant		D			1.0–1.2	5/52
Northampton Plant		D			1.0–1.2	5/52
Ebensburg	5,000	D			1.2	12/51
Ford City	6,500	D			1.2	6/51
Natrona (P)	14,000		D		1.0–1.2	12/52
Pittsburgh	600,000		D		1.0–1.2	12/52
Rhode Island						
Bristol	28,000	D			1.0–1.2	5/52
Providence	269,000		D		1.0–1.2	8/52
South Carolina						
Fort Mill (P)	3,100		D		1.0	5/51
Hartsville	5,400	S			1.0	8/51
Ninety-Six	3,000	St			1.0	8/50
Orangeburg	11,000		D		1.0	9/52
Rock Hill	15,100		D		1.0	3/52
South Dakota						
Aberdeen	22,011		D		1.2	3/51
Mobridge	3,750	S			1.2	3/52
Vermillion	5,330	D			1.2	7/52
Tennessee						
Bristol	16,721		D		0.8–1.0	7/52
Brownsville	4,668		D		1.0	5/51
Chattanooga (P)†	162,440		D		0.8–1.0	9/52
Cleveland	12,445		D		0.8–1.0	3/52
Cookeville	6,900		D		0.8–1.0	12/52
Germantown	397			S	0.8–1.0	4/52
Milan	4,941	D			1.0	3/51
Paris	8,818		D		0.8–1.0	10/52
Tiptonville	1,954		D		0.8–1.0	12/52
Texas						
Breckenridge	6,605	D			1.2	4/51
Corpus Christi	108,053	D			1.1	4/50
Graham	6,756	D			1.2	5/51

* Key to symbols and abbreviations in table: P—privately owned utility; S.D.—sanitary district; I.D.—irrigation district; D—dry-feed equipment; S—solution- or slurry-feed equipment (slurry feed is applicable only to sodium silicofluoride installations); St—saturator type feeder.

† Also supplies Rossville, Ga.

TABLE 2 (*contd.*)—*Fluoridation Plants in the United States and Canada, Dec. 31, 1952*

Locations Served	Population Served in 1950	Chemical Used			F Residual Maintained *ppm*	Date Installed
		NaF	Na_2SiF_6	H_2SiF_6		
Texas (*contd.*)						
Iowa Park	2,115	D			1.0	9/51
Marshall	22,255	D			1.0	5/46
Paris	21,636		D		1.0	10/52
Sweetwater	13,580	D			1.0	9/51
Temple	24,970	D			1.0	4/51
Tyler	38,864	D			1.0	5/52
Wellington	3,669			S	1.0	9/51
Wichita Falls	67,709	D			1.0	7/51
Utah						
None						
Vermont						
Burlington	36,000	D			1.0	8/52
S. Burlington						
Virginia						
Arlington County†	231,636		D		1.0	6/52
Charlottesville	30,469		D		1.0	11/51
Falls Church†	7,535		D		1.0	6/52
Fries (P)	1,892	S			1.0	6/52
Lynchburg	54,057		D		1.0	9/51
Norfolk	264,637	D			1.0	8/52
Portsmouth‡	92,378				1.0	8/52
Richmond	242,310		D		1.0	11/52
Winchester	13,841				1.0	
Washington						
Clarkston	5,617	D			1.0	2/52
Kennewick§		D			1.0	12/50
Norwood Village	150	S			1.0	2/52
West Virginia						
Ripley	1,800	S			0.9–1.1	4/51
Weirton	24,000		D		0.9–1.1	4/51
Wheeling	60,000		D		0.9–1.1	10/49
Bethlehem						
Williamstown	3,800	S			0.9–1.1	7/52
Wisconsin						
Antigo	9,902	D			1.1	6/49
Appleton	37,300		D		1.0	10/50
Belle Heights S.D.						
Bucholz S.D.						
Whispering Pines S.D.						
Ashland	10,640		D		1.2	10/49
Athens	823	S			1.1	3/51

* Key to symbols and abbreviations in table: P—privately owned utility; S.D.—sanitary district; I.D.—irrigation district; D—dry-feed equipment; S—solution- or slurry-feed equipment (slurry feed is applicable only to sodium silicofluoride installations); St—saturator type feeder.

† Supplied by District of Columbia.

‡ Well water with high natural-fluoride content is added.

§ Fluoridation discontinued pending installation of new equipment.

TABLE 2 (*contd.*)—*Fluoridation Plants in the United States and Canada, Dec. 31, 1952*

Locations Served	Population Served in 1950	Chemical Used			F Residual Maintained *ppm*	Date Installed
		NaF	Na_2SiF_6	H_2SiF_6		
Wisconsin (*contd.*)						
Baraboo	7,430		D		1.2	5/49
Lyons S.D.						
Beaver Dam	11,867		D		1.2	3/51
Belleville	735	S			1.0	8/51
Beloit (P)	29,590		D		1.0	4/49
Berlin	4,693	St			1.2	10/51
Blair	873	S			1.3	7/51
Bloomer	2,556	S			1.0	8/50
Cambridge	552	St			1.1	6/51
Columbus	3,250		D		1.3	8/50
De Forest	805			S	1.1	8/52
Eagle River	1,469			S	1.2	6/51
Eau Claire	36,058	D			1.2	1/51
Edgar	705	S			1.0	11/49
Edgerton	3,507		D		1.3	10/50
Elkhorn	2,935	S			1.0	4/48
Elroy	1,645			S	1.1	7/51
Evansville	2,531		D		1.0	3/50
Fond du Lac	29,936		D		1.1	7/50
Fort Akinson	6,280	St			1.0	12/49
Galesville	1,193	S			1.2	9/51
Hartford	4,549	S			1.2	1/50
Hayward	1,577			S	1.1	6/51
Horicon	2,664	S			1.1	5/52
Janesville	24,899	S			1.1	2/49
Lake Geneva	4,300		D		1.1	5/51
Madison†	102,325				1.0	6/48
Burke S.D.						
Crestwood S.D.						
Garden Homes S.D.						
Maple Bluff						
Monona						
Shorewood Hills						
Marinette	14,178		D		1.0	3/51
Marshville	12,394		D		1.1	10/50
Mayville	3,010	St			1.0	9/50
Mazomanie	963	S			1.4	9/51
Menasha	12,385		D		1.1	8/50
Menomonee Falls	2,469			S	1.3	9/51
Middleton	2,275	S			1.2	6/50
Middleton S.D.						
Mineral Point	2,284			S	1.2	11/52
Mukwonago	1,207	S			1.0	5/49
Neenah	12,437		D		1.0	3/50
Neopit	1,257	S			1.0	1/51
Oregon	1,341	S			1.1	2/50
Orfordville	543			S	1.0	9/51
Oshkosh	41,084		D		1.1	1/50

* Key to symbols and abbreviations in table: P—privately owned utility; S.D.—sanitary district; I.D.—irrigation district; D—dry-feed equipment; S—solution- or slurry-feed equipment (slurry feed is applicable only to sodium silicofluoride installations); St—saturator type feeder.

† Uses hydrofluoric acid with oil displacement type feeder.

TABLE 2 (*contd.*)—*Fluoridation Plants in the United States and Canada, Dec. 31, 1952*

Locations Served	Population Served in 1950	Chemical Used			F Residual Maintained *ppm*	Date Installed
		NaF	Na_2SiF_6	H_2SiF_6		
Wisconsin (*contd.*)						
Phillips	1,775	S			1.1	11, 50
Platteville	5,751		D		1.2	10/51
Port Washington	4,775		D		1.3	9/50
Portage	7,334	S			1.2	3/51
Poynette	969	S			1.0	10/52
Prairie du Sac	1,402			S	1.0	10/51
Racine	71,798		D		1.0	3/50
South Lawn S.D.						
Reedsburg	4,072		D		1.1	2/50
Rhinelander	8,774			S	1.1	5/50
Richland Center	4,608		D		1.2	12/49
Ripon (P)	5,619		D		1.4	6/51
Sheboygan	45,964	D			1.1	2/46
Sheboygan Falls						
Shell Lake	954	S			1.0	5/52
Soldiers Grove	781	S			1.0	1/50
South Milwaukee	12,826	S			1.1	6/52
Sparta	5,893			S	1.1	10/51
Spooner	2,597			S	1.3	5/52
Spring Green	1,064			S	1.2	12/51
Stoughton	4,833		D		1.2	9/49
Sun Prairie	2,263		D		1.2	3/50
Tomahawk	3,534			S	1.1	6/51
Trempealeau	645	S			1.0	11/52
Watertown	12,417		D		1.2	12/50
Waunakee	1,042		D		1.0	4/51
Waupun	6,725		D		1.2	11/50
Wausau	30,414		D		1.1	9/52
West Bend	7,888		D		1.0	8/50
Barton						
Westby	1,491	S			1.1	2/51
Whitehall	1,379	S			1.1	6/51
Wisconsin Rapids	13,496	D			1.2	1/51
Wyoming						
Laramie	16,000		D		1.2	8/52
Sheridan	11,400	D			1.0	5/51
Sinclair	800		D		1.2	2/52
Ontario, Canada						
Brantford	50,000	D			1.2	6/45
Brantford Twp.						
Chalk River	2,800		†		1.0–1.1	12/52
Deep River						
Fort Erie	8,500	†			1.0	1/52
Sudbury	60,000		†		0.9	8/52
McKim Twp.						
Thorold	7,500	†			1.0	2/52
Thorold Twp.						

* Key to symbols and abbreviations in table: P—privately owned utility; S.D.—sanitary district; I.D.—irrigation district; D—dry-feed equipment; S—solution- or slurry-feed equipment (slurry feed is applicable only to sodium silicofluoride installations); St—saturator type feeder.

† Type of feeder not reported.

TABLE 3

States With Ten or More Systems Using Fluoridation, 1952

State	Water Supplies Fluoridated	Population Served*	Total Urban Population*	Urban Population Served *per cent*
Wisconsin	83	755,282	1,987,888	38.0
Michigan	27	852,622	4,503,084	18.9
Minnesota	27	432,815	1,624,914	26.6
Kentucky	15	480,697	1,084,070	44.3
Indiana	14	596,707	2,357,196	25.3
North Carolina	12	594,450	1,368,101	43.4
Kansas	12	94,300	993,220	9.5
Texas	11	216,212	4,838,060	4.5
Illinois	11	164,830	6,759,271	2.4
United States	354	12,590,292	96,467,686	13.0

* Based on 1950 census.

TABLE 4

Fluoride Chemical and Type of Equipment, 1951–52

Chemical	Total Plants Reporting		Solution-Feed Units		Dry-Feed Units	
	1951	1952	1951	1952	1951	1952
Sodium fluoride, NaF	91*	147*	47	84	45	63
Sodium silicofluoride, Na_2SiF_6	66	176	1	2	65	174
Hydrofluosilicic acid, H_2SiF_6	15	32	15	32		
Hydrofluoric acid, HF	1	1	1	1		
Ammonium silicofluoride, $(NH_4)_2SiF_6$		1		1		

* One system uses both dry and solution feeders.

TABLE 5

Fluoridation Equipment and Installation Costs, 1952

Population Served*	Plants Reporting	Equipment and Installation Cost—$		
		High	Low	Median
1,000– 5,000	40	4,500	300	1,008
5,000– 10,000	13	10,000	755	1,947
10,000– 50,000	25	15,000	977	3,000
50,000– 100,000	6	20,000	1,700	
100,000– 500,000	5	23,000	2,000	
500,000–1,000,000	2	40,000	7,621	
Over 1,000,000	2	90,000	12,000	

* Based on 1950 census

TABLE 6

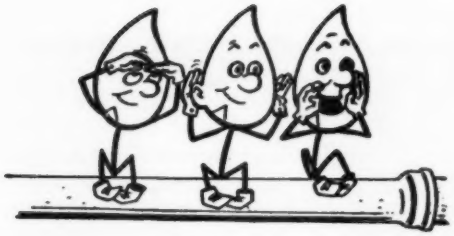
Difficulties in Feeding Fluoride Chemicals

Type of Difficulty	No. of Plants
Clogging of discharge line from feeder to point of application	24
Arching or caking of chemical in hopper	22
Chemical flow too free to permit accurate control	9
Corrosion of metallic parts of equipment by sodium silicofluoride solution	4
Solution pump failure	2
Unspecified mechanical difficulties	2
Insoluble matter in sodium silicofluoride solution	1
Objectionable amount of dust produced	1
Dust removal equipment failure	1
Pump failure due to dissolved gas released from fluoride solution	1

TABLE 7

State Fluoridation and Defluoridation Standards and Defluoridation Plants in Operation

Region and State	Minimum F Concentration Considered Effective *ppm*	F Concentration at Which Defluoridation Recommended *ppm*	Defluoridation Plants in Operation
New England			
Maine	1.0		
New Hampshire	1.0	1.5	
Vermont	1.0		
Massachusetts	1.0		
Rhode Island	1.0		
Connecticut	1.0		
Middle Atlantic			
New York	1.0		
New Jersey	1.0		
Pennsylvania	1.0		
East North Central			
Ohio	1.0		
Indiana	1.0		
Illinois	1.0	3.0	1
Michigan	1.0	2.0	
Wisconsin	1.0	2.0	
West North Central			
Minnesota	1.2	1.5	
Iowa	1.0		
Missouri			
North Dakota	1.0	3.0	
South Dakota	1.2		1
Nebraska	1.0	1.2	
Kansas	1.0	2.5	
South Atlantic			
Delaware	1.0		
Maryland	1.0		
District of Columbia	1.0		
Virginia	1.0	1.0	
West Virginia	0.8		
North Carolina			
South Carolina	1.0	2.0	
Georgia			
Florida	0.6		
East South Central			
Kentucky	1.2		
Tennessee	0.8		
Alabama	0.7	1.0	
Mississippi	1.0	1.0	
West South Central			
Arkansas	1.0		
Louisiana			
Oklahoma	0.8		
Texas	1.0	1.0	1
Mountain			
Montana	1.0	2.0	
Idaho	1.0	1.7	
Wyoming	1.2	--	
Colorado	0.5–1.5	1.5+	1
New Mexico			1
Arizona	0.5	1.5	
Utah	1.0		
Nevada	1.0		
Pacific			
Washington	0.7		
Oregon	1.0		
California	0.4–1.0		



Percolation and Runoff

The birds and the bees are not enough—Junior needs to be told about water, too, and even earlier, for water's at the beginning of the trail as well as at the Niagara Falls end of it. Strictly scientifically, we learn, those sparkling eyes so characteristic and comely in the mating female are merely the result of runoff—the female eye naturally watering more than the male eye, and the young eye naturally watering much more than the older one. As is too well known, when that runoff increases to flood proportions, even forewarning won't help—then Senior and his antecedents are carried along as well. Fortunately, perhaps, even female eyes yield to the rapid drying with age, so that by forty they water, and sparkle, and tear only half as much as they did at ten. Then, at last, it is that a female can be called a dam (or dame), her spillways open only in emergencies. Romance, though, is definitely all wet!

"The World We Inhibit" was the caption on the postmark advertisement by which Michigan State College advertised its 1953 Water Carnival, held last June 4–6. But whether the inhibitions were merely typographical or some psychoaquatic twist to the carnivalousness we have no idea. As a matter of fact, we haven't even tried to find out, preferring to remain quite ignorant of any such exhibition of inhibitions—water's or the world's. *Communists!*

Not pew in the water, but water in the pew was the subject of considerable comment among the members of one of Long Island's congregations recently when the church distributed a bulletin titled "Our Church Needs No Money!" Bring your own water, your own coal, your own candles, your own cleaning equipment; do your own preaching, your own burying and marrying, your own missionary work—and your church will need no money, was the pitch. And in spite of the fact that the sarcasm seems a little heavy considering the source, we're happy with the acknowledgment that even religion relies on water. All of which has reminded us of an April announcement from the Holy Land Nazareth Co. of Israel, advising that exporting of bottles of water from the River Jordan to Christian churches throughout the world had recently been started. Of course, even long before Moses smote the rock, water was a standby of the primitive religions—but it is good to be reminded we haven't lost what must be called a "good" customer.

(Continued on page 34 P&R)

(Continued from page 33 P&R)

The teleflush technique for judging the popularity of television programs by their effect on water pressure is by now almost old stuff. Just about every newspaper and magazine in the country has already amazed and amused its readers with reports of how the public pulse may be taken at the arteries which form its water system. And at last look, the undoubted ultimate in recognition had been achieved, when George Van Dorp and his Toledo "P" rating were squeezed into an illustrated lead article for one of those pocket periodicals—*People Today*.

Now that a real byproduct of water service can be considered reasonably well established, it certainly behooves the industry to be on guard to protect it. Already we have some cause for concern in the reprehensible tendency toward sneak commercials, intended to catch listeners too far from tap or tank to express themselves appropriately. And, elsewhere, we find for sale a new gadget called the "Half Flush," which will cut down clarity of expression by as much as 600 gal per month per person, merely by reducing the volume of water in the toilet tank. Needless to say, the sneak commercial problem will eventually solve itself—the indication of zero popularity coming even before it is entirely true. The half-flush, on the other hand, may introduce the complication of necessitating weighting the results—unless, as is quite likely, half-flushes have to be doubled or trebled often enough to counteract their conservation.

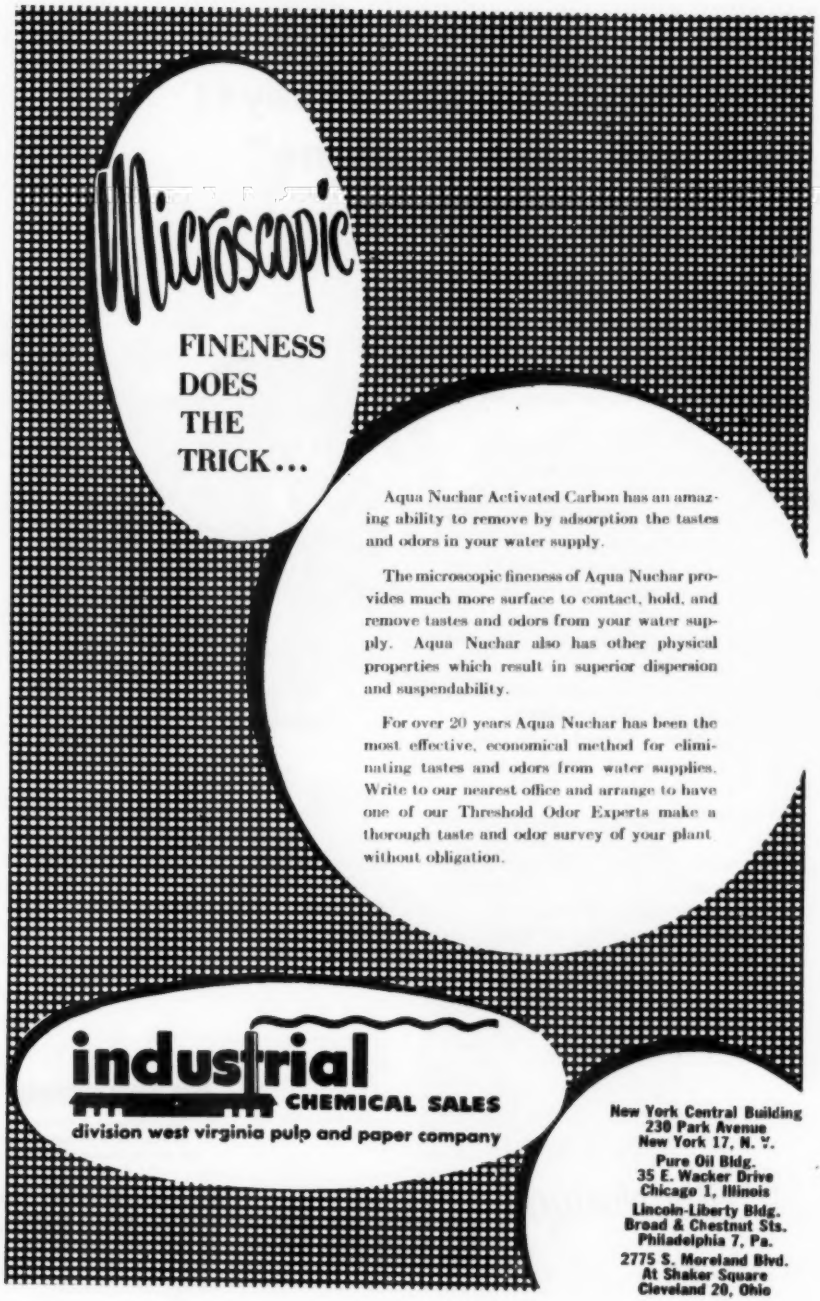
What we're much more worried about, actually, is the possibility that program directors will soon learn that boosting their own stock by an organized, say, "Flush for Uncle Miltie" campaign is much easier than dreaming up better program material. But, even then, who are we to be high-minded when business is better and droughts occur during the off-season?

Any day now in television trade journals, we can expect to find progressive water utilities advertising: "The flush with pleasure is the flush we measure!"

An engineering survey to determine whether the Delaware River channel-deepening project of the Corps of Engineers will increase salt water intrusion into ground waters is being sponsored by a number of industries in the Delaware port area. The new Fairless works of U.S. Steel Co., the Campbell Soup Co., American Water Works Co., and several other companies are cooperating in the $100,000 year-long study. Sheppard T. Powell and R. M. Leggette have been retained to make the survey.

J. T. MacKenzie, technical director of American Cast Iron Pipe Co., Birmingham, Ala., has received an ASTM Award of Merit for his leadership in the Society's cast-iron committee and his liaison work with other organizations.

(Continued on page 38 P&R)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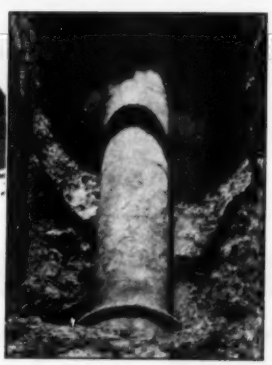

This cast iron water main, uncovered for inspection, is in good condition after 100 years of service in Alexandria, Va.—one of more than 45 cities with century-old water or gas mains in service.

pipe *for Modern Waterworks Operation*

(Continued from page 34 P&R)

What a corner of any self-respecting water works ought to look like is pictured above for those who may have some doubts about their hepness. Cornered is one of those McIlroy Fluid Network Analyzers introduced in the more respectable columns of the JOURNAL a couple years back (April 1950, p. 347). The analyzer, in case your memory has slithered, is an analogue computer designed for analyzing fluid networks, in which, by making a physical analogy of fluid flow in a pipeline with electrical flow in a nonlinear resistor, called a "fluistor," it is possible to obtain direct readings of pressure or head loss and flow rates in all members of a pipeline network. The one pictured was actually made for a St. Louis gas works and has a capacity of 491 pipes, 180 fully automatic loads, and 26 sources, but the Standard Electric Time Co. of Springfield, Mass., will be glad to design and build one to meet the special problems of your system. It is reported that one client of the company saved more than twice the cost of the analyzer in a single analysis covering a small extension to a water system, and then, of course, there will always be some use for those metal cabinets at each end of the gadget.

Picture yourself at the helm of the analyzer with all lights, buzzers, and gages flashing, buzzing, and pointing. Then, think back to the old pencil stub, slipstick, and equation, with only a dull headache to let you know the wheels were turning. It won't be long before you, too, can say: "McIlroy is here!"

A sanitary engineering group has been formed within the Metropolitan Section of ASCE in response to the demand for technical division activity on the local level. In addition to the ASCE members in the New York area who claim sanitary engineering as their prime interest, the group will be opened to nonmembers for nonvoting participation as associates. Chairman of the executive committee which has been formed to start the group functioning is William T. Ingram, associate professor of public health engineering at New York University.

(Continued on page 40 P&R)

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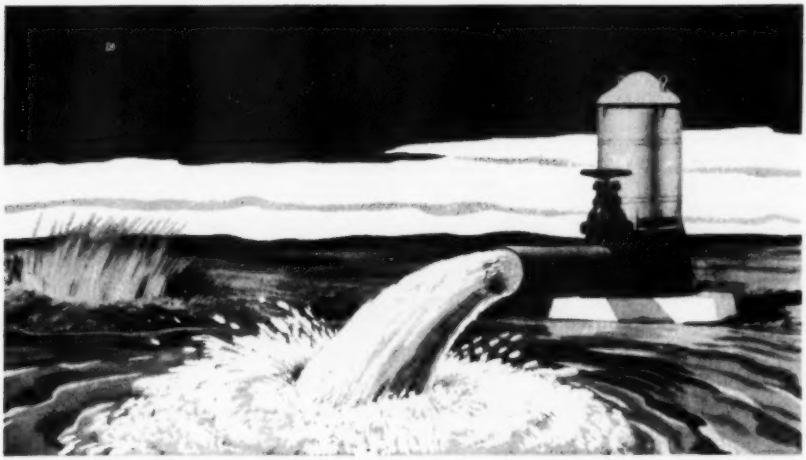

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WATER WELLS
VERTICAL TURBINE PUMPS
Water Treatment

Layne Associate Companies Throughout the World

(Continued from page 38 P&R)

Tornadoed almost into oblivion last June 8 were Lynn B. Henderson, superintendent of the water works system for the Beecher Metropolitan District of Flint, Mich., and his family. Lynn lost his house and all his personal belongings, and he and his wife had to be hospitalized, though his daughter escaped with minor bruises. The water system, meanwhile, came through unscathed, though both the elevated tank and the pumping station were on the fringe of the twister. Adapting their mutual aid system to a personal level, however, AWWA's Michigan Section, together with the Michigan Sewage and Industrial Waste Assn., rushed to the rescue with a modest purse to get him on his feet again. It was an ill wind!

"Man bites dog" is uncommon enough, but when the dog sues we have headlines. Actually the man—a mailman—didn't bite, but "viciously and wantonly stamped" on the dog—a chihuahua—and it was the dog's owner who represented him in bringing suit for $5,000 damages. Meter readers watch your step!

Claire H. Fellows, director of the Engineering Laboratory and Research Dept., Detroit Edison Co., has been elected vice-president of the American Society for Testing Materials, and will serve a two-year term. A specialist in boiler water treatment and corrosion problems, he has been active in committee and organization work in these fields.

(Continued on page 42 P&R)

the **MODERN** approach

Cast iron pipe centrifugally cast and with mechnical joints is the most efficient and economical means of modern day disribution. Serving the industry with Super de Lavaud cast iron pipe centrifugally cast in modern long lengths with standardized Mechanical Joints, Bell and Spigot or Flanged, with or without centrifugally applied cement lining. Rugged, dependable and economical.

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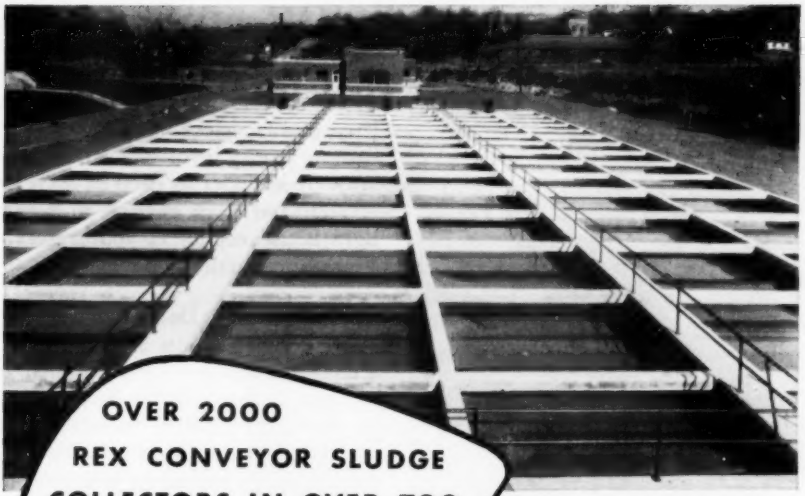

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REX CONVEYOR SLUDGE
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YES over 700 cities and industries rely on Rex® Conveyor Sludge Collectors for efficient, dependable and economical operation. They are applicable for all types of sludge handling or surface skimming conditions in either sewage, water or industrial waste treatment application.

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★ ***Centralized, Hardened Wearing Shoes***—eliminate splitting strains on wooden scraper flights.

★ ***Offset Split Drive Sprockets***—eliminate cantilevered brackets.

★ ***Double Life Sprockets***—chain engages every other sprocket tooth.

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(Continued from page 40 P&R)

A woman's place is in the swimming pool, too, as ought to be obvious from the accompanying illustration. What's going on, actually, is the morning vacuum cleaning of the bottom of Idlewild Park pool near Ligonier, Pa., where in addition to the usual sanitation practices, the bottom of the pool gets a daily sweeping. Point of the picture, really, besides supplying our annual cheesecake, is to illustrate the usefulness of the shallow-water diving apparatus developed by Mine Safety Appliances Co., Pittsburgh, Pa. With the rubberized fabric vest, oxygen cylinder, carbon dioxide exhalation canister, and facepiece, Nancy Fisher (the bathing beauty involved) can stay down an hour in water as deep as 35 ft, time enough and deep enough to do some light housekeeping in your reservoirs. Fisher is actually her name!

H. Trendley Dean, who retired in March from his post as director of the Public Health Service's National Inst. of Dental Research, has been appointed as the first full-time secretary of the American Dental Association's Council on Dental Research, in which capacity he will survey the present status and need of dental research. In the course of his work with the Public Health Service, which he joined in 1921, he directed most of the basic research on fluoridation done by that organization, and he served as consultant to the AWWA committee which won the Goodell Prize for its policy report on "The Fluoridation of Public Water Supplies" (AWWA B700; see July 1949 JOURNAL).

Amercoat Corp. has opened a new branch office at 6530 Supply Row, Houston, Tex., in place of the Dallas location at which its south-central branch was previously centered.

(Continued on page 44 P&R)

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Uniformity

NORTHROP & COMPANY, INC.
SPRING VALLEY, N. Y.

Northrop

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SELF-CAULKING
JOINT COMPOUND
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296 SOUTH STREET, NEWARK 5, NEW JERSEY

OFFICES IN ALL PRINCIPAL CITIES

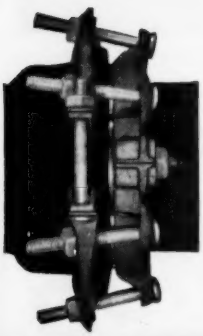
(Continued from page 42 P&R)

Lousy with doctors is a condition in which the Association will find itself if its members don't soon stop covering themselves with honors. Just this June, at least three of our lifers took the plunge to become Dr. Charles Alvin Emerson, Dr. Mac Harvey McCrady, and Dr. Samuel B. Morris. Charlie Emerson's honorers were the faculty and trustees of his alma mater, Beloit College, who conferred upon him the degree of Doctor of Science, *honoris causa,* upon the fiftieth anniversary of his graduation, for his achievements as an engineer. Mac McCrady got his at McGill University, in recognition of his position as "a foremost authority in public health bacteriology" and for his 43 years of accomplishment as a laboratorian—he, too, Doctor of Science. And it was the University of California that distinguished itself by making Sam Morris a Doctor of Laws for accomplishments too numerous and too well known to mention. Just a few more doctors and AWWA will be throwing one of its W's away and turning the other upside down.

A seminar and demonstration program on corrosion problems and prevention in the chemical industries was conducted June 18 by Atlas Mineral Products Co., as part of the Technical Assistance program of the State Department's Office of European Economic Cooperation. Among the group discussions was one on jointing materials for water and sewer pipe, led by Walter R. Pascoe, research engineer.

(Continued on page 46 P&R)

FOR REPAIRING BELL AND SPIGOT JOINT LEAKS...



The only clamp with these two important features. Gasket is completely SEALED. Massive ¾" electroplated bolts. 2"—42" incl.

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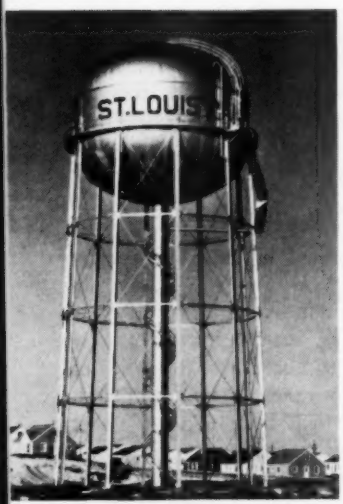

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The intrinsic design economy of our famous Double Ellipsoidal Elevated Steel Tank makes this type particularly attractive where low cost with good appearance is a major consideration. Clean cut lines without ornamentation enable savings in construction that are reflected in the purchase price. Fine, simple proportions result in a handsome structure for the community. Let us give you the details on our Double Ellipsoidal and other elevated tank types in a personal meeting, at your convenience.

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SANTA CLARA, CAL. . . . 631 Alviso Road

(*Continued from page 44 P&R*)

Training programs to be conducted by the Environmental Health Center of the Public Health Service during the coming year will include the following courses of water-supply interest:

Short Course in Fluoride Analysis	Sept. 17–18, 1953
The Membrane Filter in Bacteriological Analysis of Water	Oct. 12–16, 1953 May 3–7, 1954
Nuisance Organisms in Water Supplies	Nov. 2–6, 1953
Advanced Training for Sanitary Chemists in Water Pollution Investigations	Nov. 30–Dec. 11, 1953
Advanced Training in Bacteriological Examination of Water	Jan. 11–15, 1954
Short Course in Phenol Determination	Feb. 16–19, 1954
Advanced Training for Sanitary Engineers in Water Pollution Abatement Programs	Mar. 8–19, 1954
Bioassay of Industrial Wastes	Apr. 7–9, 1954
Short Course in the Analyses of Metals in Industrial Wastes	May 19–21, 1954
Advanced Training for Aquatic Biologists in Water Pollution Control	June 8–11, 1954
Emergency Sanitation Training	(time to be set)
Radiological Short Course —Water Works Personnel	(time to be set)

Further details on the programs, which are designed for professional personnel of health departments, pollution control agencies (including cooperating private industries), and other governmental units, may be obtained from the Officer in Charge, Environmental Health Center, 1014 Broadway, Cincinnati 2, Ohio, to whom letters of application should also be directed. No tuition will be charged, but trainees are expected to arrange for their own travel and living expenses.

Acute Augustiasis is what we've been calling what happens to us at this time every year—an incurable, but alleviable, result of both the heat and the humidity. And the agent of alleviation, of course, is water—water in at least a thousand forms and uses, to cool, to calm, and to collect. Thus, we've followed with vicarious comfort each new extension of water's coolative powers.

At Bloomington, Ind., in June, the opening of a new 5-bil gal water supply lake to public swimming and boating was one such happy thought. In New York City, the installation of a new spray device to cut down full flow of hydrants from 1,000 to 100 gpm and, so, make practical their use for street showers for the kids, was another. Still further reason to rejoice has been provided by the development of inexpensive plastic swimming pools, which can hold anywhere from 100 to 1,600 gal of fun and comfort. Meanwhile, the "Chillow"—a pad inserted between pillow and pillowcase, through which cool water is pumped—has offered off-peak alleviation. And a new automatic refrigerator ice cube maker that measures water into a disk-shaped mold, freezes it, ejects the disks into a drier, then stores them separably in a basket, all unattended, has left us anything but cold.

Where there's a will, they say, there *is* a way—but only if there's also water. Right about now, we'd guess, there's an overabundance of will in the Southwest and very little way. As a matter of fact, Augustiasis there has become allyearrounditis, almost entirely unalleviated. In that case, not what price, but what paradise, water!

(*Continued on page 48 P&R*)

proven high-rate water treatment in

less space at lower cost

Accelator®

The Accelator combines — in a single unit — mixing, coagulation and solids separation. It occupies a fraction of the space required by other types of conventional plants and greatly reduces installation costs. Softening, clarification and stabilization plus highly efficient algae and bacteria removal are obtained at the highest flow rates because of the Accelator's slurry recirculation and dynamic separation. For full details send for your copy of the informative 28-page Accelator bulletin.

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(Continued from page 46 P&R)

Tom S. Gable, formerly director of environmental health for the Flint, Mich., Health Dept., has become affiliated with the Univ. of Nebraska in the capacity of public health engineer at the Student Health Center.

Jaffe Sales Co. of Chicago has been appointed sales representative of the Kitson Valve Div., Welsbach Corp., for the Chicago-Milwaukee areas. The Chicago office of the firm is managed by Adolph and Jack A. Jaffe; the Milwaukee office by Herbert Schroeder.

Wallace & Tiernan, Ltd., of Canada has moved to its new headquarters in Scarborough Township, Ont., eight miles from Toronto. The attractive, modern building will house the firm's offices and manufacturing plant.

A differential controller for changeover valves has been designed by Rockwell Mfg. Co. to permit automatic introduction of additional orifice meters when wide variations in flow exceed the scale limits of the regular measuring instrument. The device utilizes a four-way valve, with the secondary meter on a parallel line. When flow returns to normal, the valve is repositioned, and the extra meter is removed from the circuit. Hydraulic pressure is used to operate both controller and valve.

A new ink feed reservoir for recording instrument pens, the Squier Everite, is made of lightweight plastic and holds an 8-day supply of ink. Attachment to all makes of instrument pens is said to be simple.

(Continued on page 76 P&R)

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Buffalo AMERICAN Meters are simply designed, with fewer working parts — save money for you through lower maintenance and replacement costs. Write for details.

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Whether your city's water works system is 100 years old . . .

Famous "4 Corners," Rochester, N. Y., in 1830—Illustration courtesy of Rochester Chamber of Commerce

—or you are planning an expansion program

EDDY Mechanical Joint Hydrants...

will fit any pipe in your water distribution system

No matter how old your present system is—no matter where, how or when made—Eddy Hydrants are ideally suited for emergency replacement or expansion of your existing facilities. They can be quickly installed in any kind of weather or in a flooded trench. A ratchet wrench is the only tool needed! One man can remove all operating mechanism for inspection or repair.

And no matter how far into the future your city planning is projected, Eddy Hydrants are your best long term investment. Large waterways insure a plentiful flow of water. Hydrant opens smoothly with the pressure and closes without water hammer. Stem held in place below main valve means no water loss due to a bent stem. When in closed position, the hydrant barrel is automatically drained by positive drip action to prevent freezing. Eddy Hydrants are bronze mounted throughout.

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WATERFORD, NEW YORK

The Reading Meter

Chemical Engineering Costs. *O. T. Zimmerman & Irvin Lavine, ed. Industrial Research Service, Masonic Bldg., Dover, N.H. (1950) 419 pp.; $7*

This unusual volume contains a wide array of comparative cost data on various aspects of chemical processing, and includes chapters on pumps, water conditioning, and "industrial materials," which include pipe, valves, water meters, and motors. The editors are also responsible for the *Chemical Engineering Costs Quarterly*, a late issue of which contained an article on steel storage tank costs. Although costs may change in time, and the authors of specific chapters may be preoccupied with their own commercial products, the fact that definite amounts are given facilitates comparisons and evaluations that have a good chance of remaining relatively useful until technical obsolescence interferes. The book should be helpful in arriving at engineering decisions on new projects or installations.

Review of Current Research and Directory of Member Institutions, 1953. *Engineering College Research Council, American Society for Engineering Education, 103 Mechanical Engineering Bldg., Pennsylvania State College, State College, Pa. (1953) 330 pp.; paperbound; $2.50*

An index to approximately 7,500 engineering research projects, on which $65,000,000 are spent annually, this book is issued every other year to aid in coordinating research efforts. Basic data on the member colleges and institutions are included, and even water works and other short courses are listed.

Source Materials on Water Pollution Control. *Div. of Water Pollution Control, Public Health Service, Washington 25, D.C. (1952) 23 pp.; paperbound; free*

More of an introduction to the subject than a complete bibliography, this booklet has the merit of listing the source and price of the documents it indexes. At that, many of them are distributed by the Service without charge. The various references are grouped under such subject headings as "Community Action," "Financing and Economic Factors," "Laws and Regulations," "Water Resources," and others.

The Seventh Sense. *Kenneth Roberts. Doubleday & Co., Inc., Garden City, N.Y. (1953) 337 pp.; $4*

Grosser than *Henry Gross and His Dowsing Rod*, though not nearly so engrossing, is this sizzling sequel, in which Kenneth Roberts proves to his own complete satisfaction not only that dowsing works (and works for money), but that "water geologists" are a bunch of closed-minded crackpots who have a vested interest in current ground water theory and terminology that won't permit them to see the light of Henry's domes and veins. That light, incidentally, would convince you that "a water dome almost always rises to a hilltop from deep underground in a sort of tube or chimney . . . within the confines of [which] a mass of water wriggles and zigzags upward until portions of it encounter cracks or fissures through which single veins flow out in all directions, just as branches emerge from the upper part of a tree." The hydrologic cycle, meanwhile, is left out

(Continued on page 52 P&R)

1935·1953

18 YEARS OF LOW COST WATER PURIFICATION

In 1935 this %Proportioneers% Heavy Duty Midget Chlor-O-Feeder was installed at the Canobie Lake Recreation Company, Salem Depot, New Hampshire. Here you see it about to be returned to active service after being completely overhauled at the factory. This unit was the *second* Heavy Duty Midget Chlor-O-Feeder to go into service anywhere in the world — now, because of interchangeability of parts, completely modernized ready for another 18 years of service.

CHLOR-O-FEEDER FEATURES:

- Low first cost
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- Ease of installation and removal
- Packaged unit including all accessories
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Now let's review the actual expenses involved in this installation. Total cost, including installation, amortization and maintenance, for safeguarding the health of the patrons of the Canobie Lake Park has been less than $19.00 per year. This is a typical performance record for %Proportioneers% Heavy Duty Midget Chlor-O-Feeder.

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The Reading Meter

(*Continued from page 50 P&R*)

in the cold, used only to provide "motionless deposits [of underground water] such as are punctured by so-called artesian wells." And the "seventh sense," if you haven't already guessed, "is the working of a dowsing rod, or its equivalent, in the hands of a competent dowser, on flowing underground water."

"Grosser," we say, in being more insistent and more commercial than Roberts' best-selling dowsiness of two years ago; "less engrossing," we feel, for having dropped such fascinating divinations as that of gold, bourbon, and the sex of unborn children; and "sizzling," certainly, in its every mention of skeptics, science writers, and, most especially, "water geologists." Notable among those selected for sizzlification (for our unkind words about his opening opus) is the American Water Works Association, eventually brushed off as "a mere trade association . . . [with] a paid staff of only ten or twelve employees," hardly worth worrying about and no longer to be confused with the mighty, and mighty friendly, American Water Works Co. The AWWCo., then, and President John Ware, a dowser in his own right, rate a whole chapter in the book—a chapter which begins like a honeymoon and ends in a huff. And even the huff is interesting in that it demonstrates Roberts' contempt for the prowess of other dowsers. As a matter of fact, while he would have us believe that dowsing is the answer to the world's water resources problems, he indicates a maximum of eight dowsers competent enough to be "wholly reliable"—which makes the twig that Henry bears a rather heavy one.

Even if you believe, are inclined to believe, or don't disbelieve in dowsing (and the names of Henry's paying customers include at least one of our eminent consulting engineers), the *Seventh Sense* isn't likely to appeal to you. As scientific proof, it's a useless collection of hearsay and rationalization. As reading matter, it's the dull and repetitious result of agglomerating trivia, correspondence, and peevishness. As grist for P&R, it may well be worth space on our bookshelf for paragraphs such as this:

> Unlimited water, to my definite knowledge, is an overwhelming necessity to any home or enterprise. People can get along without automobiles, without mink coats or telephones, without furnaces or ice chests, without the alcoholic beverages so highly lauded in double-page advertisements by Men of Distinction, without radio or television, without underwear or winter overcoats if need be; but they can't get along without water.

For your library, however, better Mickey Spillane on water purification.

Surface Water Supply of Virginia: James River Basin, 1942–1950. *Bul. 13, Div. of Water Resources, Virginia Dept. of Conservation & Development, Box 1338 University Station, Charlottesville, Va. (1952) 394 pp.; paperbound; free*

Stream flow stage and discharge at various gaging stations on the James River and its tributaries are presented in this report, one of four prepared cooperatively by the U.S. Geological Survey. In addition to the day-by-day detailed readings, annual summaries of maximum, minimum, and mean discharge, and total watershed runoff are presented for all the years of record. The data provide a useful supplement to more general reports on Virginia's water resources (*see* September 1952 JOURNAL, p. 80 *P&R*).

Surface Water Supply of Virginia: Chowan and Roanoke River Basins, 1942–1950. *Bul. 14, Div. of Water Resources, Virginia Dept. of Conservation & Development, Box 1338 University Station, Charlottesville, Va. (1953) 333 pp.; paperbound; free*

Another of the series of reports, prepared cooperatively by the U.S. Geological Survey, presenting gaging records for the eight-year period, plus summaries as far back as the records go.

(*Continued on page 54 P&R*)

The

FORD COPPERHORN

SLASHES TIME ON VERTICAL METER SETTINGS

The Ford Copperhorn provides the ideal setting for a meter on vertical piping. Installation requires but one or two cuts and threads and eliminates the many pipe fittings usually required to set the meter upright.

Not only does it slash labor and time, but it actually cuts the pressure loss to less than half of what it would be through the fittings it replaces. Oversize copper tubing and wide, sweeping curves offer practically no resistance to the flow of water.

Best of all, the setting is permanently aligned for fast meter changes. Construction is entirely of copper and bronze. No electrical bonding required around meter.

For further information, send for new Ford Catalog No. 50.

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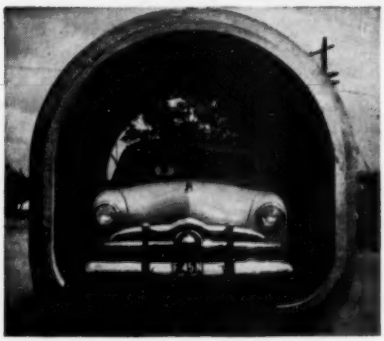
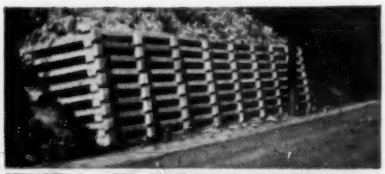


26 plants for convenient, economical service.

30 years' experience in pipe, cribbing, precast manholes, riverweights, flat base pipe. Name it, we make it!



UNIVERSAL
CONCRETE PIPE CO.
297 South High Street
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Publishers of Famous "Pipe Dreams"

The Reading Meter

(Continued from page 52 P&R)

Surface Water Supply of Virginia: New, Big Sandy, and Tennessee River Basins, 1942–1950. *Bul. 15, Div. of Water Resources, Virginia Dept. of Conservation & Development, Box 1338 University Station, Charlottesville, Va. (1953) 296 pp.; paperbound; free*

Through some happy afterthought, this report has an index to gaging stations, missing in the others of the series.

Individual and Community Health. *William W. Stiles. The Blakiston Co., New York (1953) 499 pp.; $6*

This textbook of health education covers somewhat too broad a field to pretend to serve as more than an introduction to the various subjects it surveys, but the author appears to have been painstaking and thorough in his approach. The water supply chapter is a lightening tour, stopping longest, as is to be expected, on individual usage (farm wells, emergency disinfection, drinking fountains), but visiting the community water works long enough to convey the idea that it is a busy and responsible place. Perhaps it might have been better, in this context, to mention that treatment is not confined to purification, than to attempt to deal with the taste and odor problem by the fallaciously simple expedient of aeration alone.

Industrial Water Resources of Canada: *Columbia River Drainage Basin in Canada, 1949–1950. J. F. J. Thomas. Water Survey Report No. 4, Report No. 838, Mines Branch, Dept. of Mines & Technical Surveys, Ottawa, Ont. (1953) 80 pp., map; paperbound; $0.75*

In addition to giving the analyses of waters at various sampling stations in the Canadian portion of the Columbia River system, basic data on municipal water supplies within the drainage basin are provided. Population served, ownership, supply sources, treatment, storage, and extent of consumption (including industrial uses) are included.

how to save... a quarter million dollars

A large mid-western city recently was faced with this problem. Within eight years after the water treatment plant was placed in operation, the submerged steel showed active corrosion of alarming proportions — the warning of a possible loss of a quarter million dollar investment. Various coatings were tested for possible application, but none of those tested was considered satisfactory.

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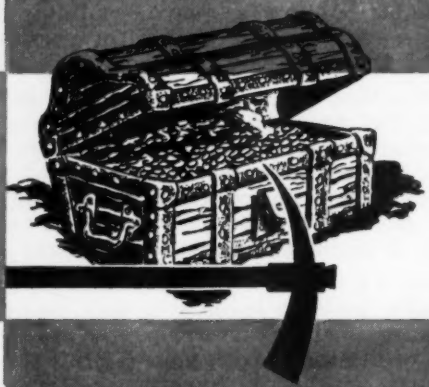

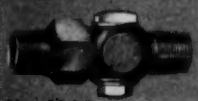

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Condensation

Key: In the reference to the publication in which the abstracted article appears, **39**:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, **39**:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

ANNUAL REPORTS

Community: **Oak Park, Ill.**
Reporting organization: Water Dept.
Year ending: Dec. 31, '52
Population served: 65,000
Customers: 12,379
Source of supply: L. Michigan through Chicago water system
Water produced (mil gal): 2,087
Water sold (mil gal): 1,867
Water unaccounted for (%): 9
Consumption (mgd): max.: 8.0; avg: 5.7 (88 gpcd)
Metered services (%): 100
Mains (mi): distr. and trans., 108.88
Valves: 1,007
Hydrants: 1,126
Revenue ($): water: 637,358; other: 4,710; total: 642,068
Expense ($): op. and maint.: 414,087; depn.: 11,577; total: 425,664
Tax paid (% of revenue): none
Income ($): 216,404
Paid to general funds ($): 360,777
Unit costs ($/mil gal): water: 120; power: 5.64
Water analysis: avg monthly water temp. (°F): high (Sept.): 67; low (Jan.): 38.

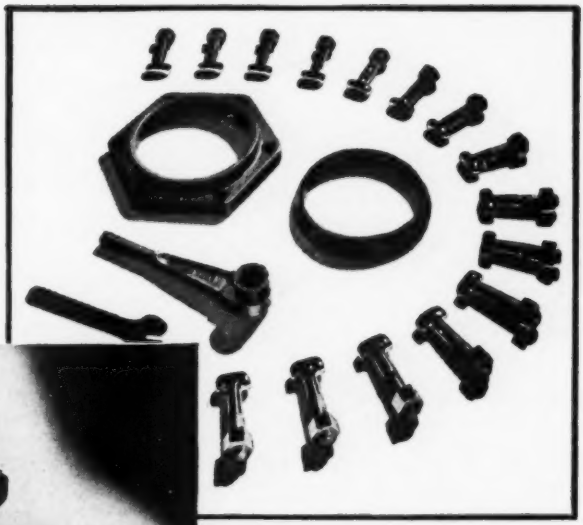
Community: **Greenville, S.C.**
Reporting organization: Water Dept.
Year ending: July 31, '52
Revenue ($): water: 731,375; other: $57,035; total: 788,410
Expense ($): op. and maint.: 155,354; general office salaries: 52,007; depn.: 121,745; other: 143,454; total: 472,560
Tax paid ($): 25
Income ($): 315,850
Bond interest ($): 33,862
Bond retirement ($): 180,000
Book value ($): 9,185,513
Debt outstanding ($): 4,920,000
Surplus ($): 620,969.

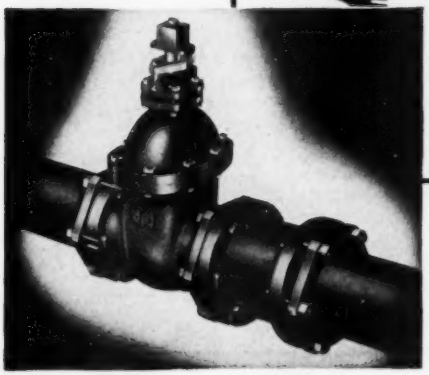
Community: **Fort Worth, Tex.**
Reporting organization: Water Dept.
Year ending: Sept. 30, '52
Population served: 323,000
Customers: 84,979
No. of employees: 320
Source of supply: surface (lakes)
Type of treatment: aeration, filtration
Water produced (mil gal): 14,512
Water unaccounted for (%): 11.5
Consumption (mgd): max.: 78; avg: 40.3 (125 gpcd)
Metered services (%): 100
Mains (mi): distr. and trans., 912.12
Hydrants: 4,246
Distr. storage (mil gal): 16.93 (elevated); 11.0 (clear well capacity)
Revenue ($): water: 3,545,916; other (sewer service): 1,022,567
Expense ($): op. and maint.: 1,543,761; depn.: 521,145; other: 807,250; total: 2,872,156
Tax paid (% of revenue): none
Income ($): 1,696,327
Bond interest ($): 275,429
Bond retirement ($): 185,000
Added to reserve ($): 189,322
Debt outstanding ($): 22,606,485
Unit costs: water ($/mil gal): 8.11
Treated water analysis (ppm): turbidity: 0; total alky.: 124; phenol alky.: 1; residual Cl: 0.50; hardness: 136; max. MPN (raw water): 471; max. temp. (raw water): 86°F
Other items: City forces installed 261,302 ft of new mains, with contractors laying 76,430 ft.

Community: **Arlington County, Va.**
Reporting organization: Dept. of Public Service
Year ending: June 30, '52
Population served: 147,000
Customers: resid.: 23,183; coml.: 1,250; apartment: 1,555; total: 25,988

(Continued on page 64)

ALL YOU NEED





IS: A RATCHET AND OPEN END WRENCH, THREE RUBBER GASKETS, THREE CAST IRON FOLLOWER RINGS AND A HAND FULL OF BOLTS AND NUTS ***TO INSTALL***

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Write for Bulletin No. MJ2.

37

THE A.P. SMITH MFG. CO.

EAST ORANGE, NEW JERSEY

(Continued from page 62)

No. of employees: 77
Source of supply: Dist. of Columbia treated water
Type of treatment: filtered
Water produced (mil gal): 5,280.1
Consumption (mgd): max.: 20.8; avg: 14.6
Metered services (%): 100
Mains (mi): distr. and trans., 323.97
Hydrants: 1,852
Revenue ($): water: 555,203; other: 387,779; total: 942,982
Expense ($): op. and maint.: 710,915
Tax paid (% of revenue): none
Income ($): 232,067
Bond interest ($): 1,062
Bond retirement ($): 850.00
Capital outlay ($): 376,800
Paid to general fund ($): 215,834
Debt outstanding ($): 21,240
Unit costs ($/mil gal): treated water: 63; power: 2.7; trans. and distr.: 41; administration and general: 24
Rates (residential): service charge, $1.50/quarter; 15.6¢/1,000 gal
Other items: Fire hydrants inspected every 6 mo and painted every 2 yr under newly inaugurated maintenance program. Charge for water main installation is $2.50/front ft for each lot served.

Community: **Richmond, Va.**
Reporting organization: Dept. of Public Utilities
Year ending: June 30, '52
Population served: 236,200
Customers: 56,426
Source of supply: surface
Type of treatment: aeration, coagulation, filtration
Water produced (mil gal): 10,756
Water sold (mil gal): 9,850
Water unaccounted for (%): 8.5
Metered services (%): 100
Mains (mi): distr. and trans., 573.95
Hydrants: 3,356
Distr. storage (mil gal): 2.0 (elevated); 2.15 (ground)

(Continued on page 66)

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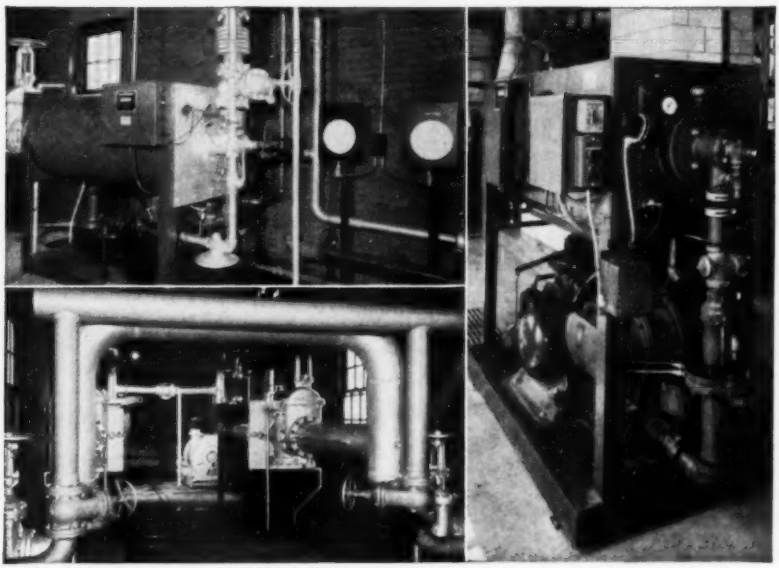

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WRITE FOR BULLETIN 7W64

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PROCESS EQUIPMENT

FACTORY • ENGINEERING OFFICES • LABORATORY
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(*Continued from page 64*)

Water analysis (ppm): turbidity: 28; color: 65; alky.: 47; pH: 7.0; BOD: 5.6; temp.: 59°F
Rates (¢/100 cu ft): inside city: 6–15; outside city: 6.5–32.5.

Community: **Green Bay, Wis.**
Reporting organization: Water Dept.
Year ending: Dec. 31, '52
Population served: 53,200
Customers: 13,765
Source of supply: wells
Water produced (mil gal): 2,395
Water sold (mil gal): 2,082
Water unaccounted for (%): 12
Consumption: max.: 10.7 mgd; avg: 123 gpcd
Metered services (%): 100
Mains (mi): distr. and trans.: 155.92
Hydrants: 899
Revenue ($): water: 419,374; other: 1,073; total: 420,477
Expense ($): op. and maint.: 197,334; depn.: 42,334; other: 95,678; total: 335,346
Tax paid (% of revenue): 14.7
Income ($): 85,101
Bond interest ($): 33,563
Added to reserve ($): 73,359
Debt outstanding ($): 683,000
Unit costs ($/mil gal): power: 36; labor: 8.35.

—*J. E. Vogt*

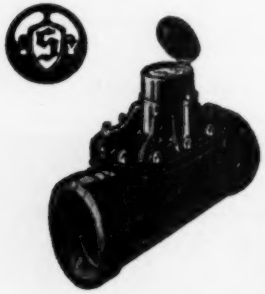
CHEMICAL ANALYSIS

Photocolorimetric Determination of Free Chlorine in Water. J. E. Goris & J. L. de Hauss. Chim. Anal., 35:41 ('53). Colorimetric detn. of free Cl in water is usually based on treatment of sample with 0.1% soln. of *o*-tolidine and measurement of resulting yellow coloration. In studying best conditions for carrying out measurement, it was found advantageous to use monochromatic violet filter for concns. of 0–0.5 g. Cl per cu m and blue filter for larger concns. As now prescribed, method is rapid and well reproducible so that it is of interest industrially.—*CA*

Chlorinated Water. A. T. Palin. Brit. Pat. 680,427 ('52). Method is described for accurate detn. of free or available Cl in chlorinated water, which utilizes neutral *o*-tolidine (aq. *o*-tolidine dihydrochloride contg. only sufficient HCl to stabilize compd.) in conjunction with suitable dispersing agent and buffer. Na hexametaphosphate is preferred dispersing agent, and mixt. of NaH_2PO_4 and Na_2HPO_4 may be used as buffer. In carrying out detn., not less than 2 ml each of 4% soln. of Na hexametaphosphate and of 0.1% soln. of neutral *o*-tolidine are mixed in titration flask. After adding 100 ml of sample of chlorinated water, titrate mixt. with standard soln. of ferrous ammonium sulfate (Reading 1); then add 2 ml of 0.1% soln. of KI and continue titrating (Reading 2). Add 2 ml of 0.5% soln. of H_2SO_4 followed by 2 ml of 5% soln. of $NaHCO_3$, and again continue titrating (Reading 3). Reading 1 corresponds to free Cl including NCl_3 (if present), Reading 2 to monochloramine, and Reading 3 to dichloramine. If it is desired to differentiate between free Cl and NCl_3, latter is extd. with CCl_4 and titrated separately.—*CA*

Induced-Reaction Method for Determination of Fluoride Ion. J. L. Lambert. Anal.

(*Continued on page 68*)



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193

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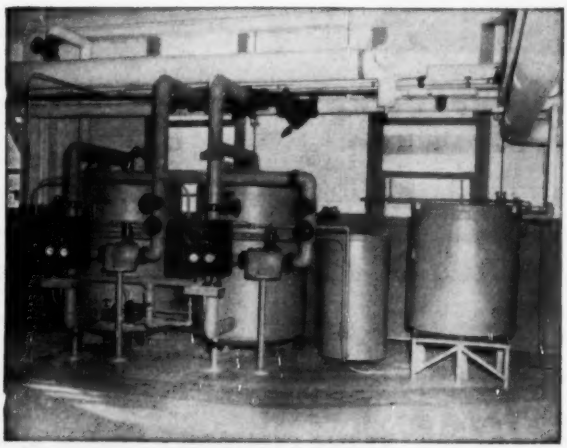
(*Continued from page 66*)

Chem., **25**:271 ('53). Method gives good results in detg. 0.3–0.9 ppm of F in drinking water. It is based on speeding up of reaction between I^- and hydrolysis products of $Ce(SO_4)_2$ which is measured by timing appearance of blue starch triiodide. To 250 ml of water, add 1.0 ml of cerate reagent prepd. from 10 ml of satd. $Ce(HSO_4)_4$ soln., 7.0 ml of concd. H_2SO_4, and water to make 0.5 l. After thorough mixing, transfer to test tube and place in thermostat at desired temp. After 10 min add 1.0 ml of reagent prepd. from 11 g CdI_2, 2.50 g of twice recrystd. potato starch in 1 l of soln. Take time from addn. of this reagent until blue color develops matching blue comparison soln. which is 0.1*M* in Na_2HPO_4 with sufficient bromothymol blue to give perceptible color. —*CA*

Determination of Fluoride in Water by the Aluminum-Hematoxylin Method. M. J. Price & O. J. Walker. Anal. Chem., **24**: 1593 ('52). Bleaching of Al-hematoxylin lake by F^- can be used for detg. 0–1.5 ppm of latter with accuracy of 0.05 ppm if recrystd. hematoxylin oxidized with H_2O_2 is used at pH 4.6. To 55 ml 0.009*N* HCl, previously heated to approx. 60°, add 0.1 g hematoxylin, recrystd. 3 times from water contg. small amt. of $NaHSO_4$, and heat on water bath with shaking until soln. is complete. While still warm, add 0.02*N* NaOH until soln. just turns red, and then 3 ml 3% H_2O_2, followed by 100 ml 1% AcOH, and allow to stand 1 hr. To 100-ml standard $Al_2(SO_4)_3$ soln. (0.05 ppm Al) dild. with 850 ml distd. water, add 25 ml satd. $NaHCO_3$, while stirring, and 15 ml of hematoxylin soln. Mix and allow to stand 1 hr, add 10 ml 1:2 AcOH, shake, and let stand 48 hr before use as reagent for F^-. To 100 ml of water contg. up to 1.5 ppm F^- (higher concns. can be dild. with distd. water) add 10 ml reagent, allow to stand 4 hr, measure transmittancy in photoelec. colorimeter with 550-mμ color filter, and read F^- concn. from calibration curve prepd. from solns. of known F^- content

(*Continued on page 70*)



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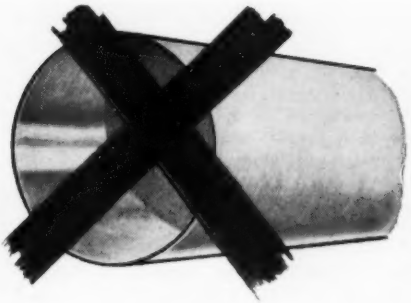

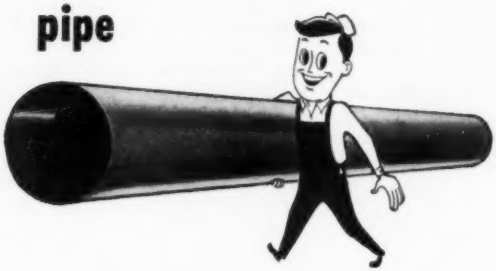

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(Continued from page 68)

treated in same manner. Some interference occurs when SO_4^{--} is as high as 200 ppm; correction for 1,000 ppm is approx. 0.2 ppm F^-. With F^- concns. of 0.4–1.4 ppm, effect of PO_4^{---} up to 8 ppm is negligible: with lower F^- concns., corrections of 0.1–0.4 ppm are necessary. Fresh reagent soln. should be prepd. each week.—*R. E. Thompson*

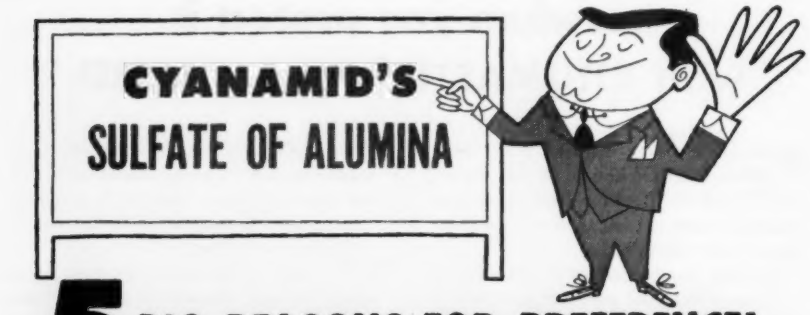
Colorimetric Determination of Nitrates in Water With Phenolsulfonic Acid. R. SIJDERIUS. Chem. Weekblad, **48**:518 ('52). Presence of up to 20 mg of Cl^- does not affect detn. by this method. Add to sample 1 ml of phenolsulfonic acid and evap. to dryness. Transfer soln. to 100-ml volumetric flask, add 5 ml of 25% NH_3 soln., and dil. with water to 100 ml. Measure extinction at 430 mμ. This method can be used for samples contg. 0.1–1.0 mg of nitrate. In samples with less than 0.1 mg of nitrate, accurate detn. can be made by adding known amt. of nitrate. Presence of up to 0.5 mg of NH_4^+, 20 mg of Ca^{++}, 5 mg of Mg^{++}, 0.5 mg of Cu^{++}, 0.25 mg of Cl_2, 12.5 mg of CO_2, and 0.1 mg of NO_2 per sample does not interfere. —*CA*

Determination of Nitrite in Mineral Waters Containing Hydrogen Sulfide. N. IKEDA. J. Chem. Soc. Japan, Pure Chem. Sec., **73**:551 ('52). To remove H_2S, which interferes with detn. of nitrite in water, suspension of $CdCO_3$ is added. CdS formed is filtered, and nitrite is detd. by Griess-Romijn reagent in usual way. Examples of application to mineral waters are given.—*CA*

The Determination of Nitrogen Compounds and Iron in Smallest Amounts of Drinking Water With Pulfrich's Photometer. R. MEYER & J. BUNGER. Gesundh.-Ing., **73**:367 ('52). Methods are proposed for N and Fe detn. in small amts. of water by using Pulfrich's photometer. Detn. of even small amts. possible in short time.—*CA*

Determination of Phenols by the *p*-Nitrosodimethylaniline Method. R. H. HILL & L. K. HERNDON. Sew. Ind. Wastes, **24**:1389

(Continued on page 72)



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(*Continued from page 70*)

('52). Method is given for detn. of phenol in industrial wastes. Method depends upon reaction of *p*-nitrosodimethylaniline with phenol to produce blue color. Comparisons are made with spectrophotometer at 650 mμ. Sensitivity is approx. 5 parts per billion.—*CA*

So-called Silica Content of Natural Waters. I. IWASAKI, T. KATSURA & T. TARUTANI. Bul. Chem. Soc. Japan, **24**:227 ('51). Partition of silica compds. between colloidal and dissolved states in river, sea, and hot-spring waters was detd. Aged water was higher in colloidal silica than freshly analyzed samples. Colloidal silica particles with diam. larger than 2–3 mμ do not give coloration with acidic ammonium molybdate.—*CA*

Field Estimation of Sulfites in Waters. S. SUSSMAN & I. L. PORTNOY. Anal. Chem., **24**:1652 ('52). Following method was developed for estn. of up to 250 ppm. SO_3^{--} in boiler water to nearest 25 ppm in field and to nearest 10 ppm in lab. Into 2-oz French square, screw-cap bottle (capac. 65 ml) calibrated at 25 ml, introduce 25 ml of dichromate reagent (prepd. by dissolving 0.246 g $K_2Cr_2O_7$ in distd. water, adding 40 ml concd. HCl dild. with 80 ml distd. water, and making up to 1 l), collect sample by filling bottle, cap quickly, shake, and compare with color stds. On return to lab., exam. in photoelec. colorimeter with blue filter (KS-42, approx. 420 mμ). Stds. are prepd. by dissolving weighed portions of Na_2SO_3 (5 mg = 25 ppm) in 200 ml of boiled distd. water to which 125 ml of dichromate reagent has been added. Filtration after mixing with reagent minimizes interference from turbidity. Conversion of suspended Fe oxides to yellow $FeCl_3$ does not significantly interfere. Filtration through activated C to remove tannin color results in reduction in detd. Na_2SO_3 concn., but this is well within accuracy of method. Reaction is apparently not rigidly quant., but this is not necessary if results are reproducible. Up to approx. 175 ppm, Na_2SO_3 is apparently oxidized to dithi-

(*Continued on page 74*)

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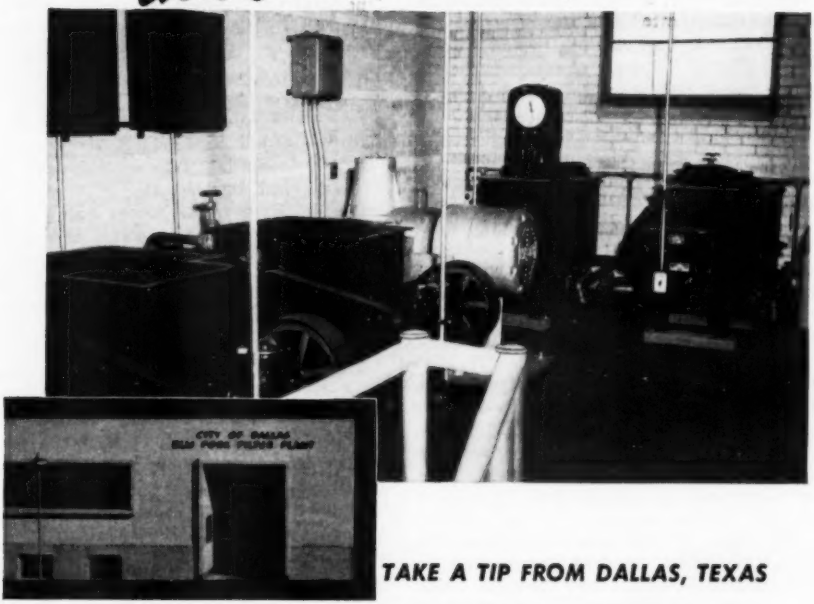

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B-I-F INDUSTRIES **OMEGA** THE LAST WORD IN FEEDERS OMEGA

(Continued from page 72)

onate; above this concn., oxidn. probably proceeds increasingly to SO_4^{--}.—*R. E. Thompson*

Determination of Heavy Metals and Silica in Chromate-treated Cooling Waters. S. Sussman & I. L. Portnoy. Anal. Chem., **24**:1644 ('52). By means of cation-exchange resin Dowex 50 (and probably any other sulfonated, polystyrene type exchange resin) it is possible to remove Cu^{++} and Fe^{+++} from cooling waters contg. chromate, although erratic results were obtained when Fe content exceeded 12 ppm. To det. Si, anion-exchange resin was used to prevent interference of CrO_4^{--}. Cation-exchange resin could be easily regenerated by treatment with 5% HCl, but it is often more convenient in SiO_2 detn. to use less resin and discard it after using.—*CA*

Determination of Microgram Quantities of Thorium in Water. E. Taylor & R. T. Dillon. Anal. Chem., **24**:1624 ('52). Procedure is described for detg. Th by modification of method of Thomason *et al.* after concn. by pptn. as oxalate with Ca. Heat four 1.5-l samples almost to boiling and add to each 1 ml 37% HCl, and to 2 of them 10 γ Th nitrate. Ppt. oxalates by method of Willard and Furman, filter through Selas No. 3010 crucibles, convert to carbonates by heating, and weigh. Treat crucibles and contents with 1 ml 37% HCl in filtering funnels with outlets leading into 15 × 125-mm tubes graduated at 6 and 10 ml, followed, under gentle suction, by very fine stream of redistd. water to total vol. of nearly 6 ml. Dry and weigh empty crucibles. To each tube add 2 ml 10% $NH_2OH \cdot HCl$, boil gently approx. 1 min, add 1 ml 0.1% soln. of Na salt of 1-(*o*-arsonophenylazo)-2-naphthol-3,6-disulfonic acid (**I**), and dil. to 10 ml. Prep. reference soln. by suspending in 10 ml redistd. water twice avg. wt. of $CaCO_3$ found above, adding 1:1 HCl dropwise to 10 drops in excess of amt. required for soln., 4 ml 10% $NH_2OH \cdot HCl$, and 2 ml **I**, and dilg. to 20 ml. Compare absorbency of 4 samples and reference soln. in Beckman Model DU spectrophotometer, by setting slit opening at 0.0355 mm and wavelength at 545 mμ, and est. Th concn. from relative absorbency of control samples and samples to be analyzed. Mg, Na, K, and Si do not interfere. Interference by Fe is rendered negligible by reduction with $NH_2OH \cdot HCl$. Avg error with $CaCO_3$ solns. contg. 0–10 γ Th was 0.17 γ, and with solns. contg. Ca, Mg, K, Si, and Fe somewhat higher.—*R. E. Thompson*

Quantitative Spectral Analysis of Trace Elements in Water. S. Wilska. Acta Chem. Scand., **5**:1368 ('51) (in English). Application of porous-cup electrode technique for direct spectral analysis of solns. is described with reference to trace analysis of water. Ca and Mg compds. were used as internal standards. It was also detd. that Pt was ideal internal std. because it has reasonable no. of contamn.-free lines covering wide wavelength range and it is absent from Finnish waters. Concn. of 30 ppm of Pt was optimum. Following min. concns. were capable of dtn. in original water samples: Al 0.5, Ba 0.05, Cd 0.01, Co 0.05, Cu 0.01, Cr 0.05, Fe 0.05, Mn 0.001, Ni 0.5, Pb 0.5, Sr 0.07, and Zn 0.6 ppm. Avg percentage deviation from mean intensity ratio (analysis line/internal standard line) varied from 1.49% (Cd) to 4.35% (Mn). Use of method to det. adsorption isotherms is mentioned.—*CA*

Exchange Titrimetry. L. Lescoeur. Ann. Inst. Hydrol. Climatol., **22**:51, 59 ('51–'52). Total concn. of cations in aq. soln. can be detd. by passing portion of soln. through column of Zeocarb previously equilibrated with HCl, and titrating effluent with NaOH. Data on compns. of some natural waters found by this method are in generally good agreement with values predicted from complete analyses. pH of soln. after exchange with Zeocarb, which is related to concns. and hydrolysis consts. of anions present, allows further characterization of sample.—*CA*

OTHER ARTICLES NOTED

Recent articles of interest, not abstracted, are listed below.

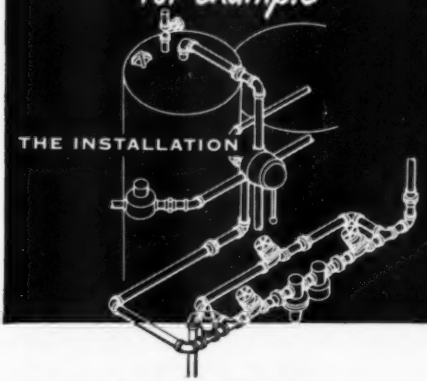
Civil Defense for Water Supplies. F. H. Kingsbury. Pub. Wks., p. 65 (Apr. '53).

Plastic Pipe: What's Its Future? Anon. Eng. News-Rec., **150**:19:37 (May 7, '53).

Repair Shop and Test Program for Large and Small Meters. J. E. Moses. Wtr. & Sew. Wks., **100**:146 (Apr. '53).

This Valve Stops the "Up" in Upkeep

...on Water Service Piping, for example



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At the Excello Paper Products Co., Inc., Cincinnati, using Crane Diaphragm valves on city water supply lines; also on plant service water piping, hot and cold.

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Typical of many processes using a lot of water, this plant has numerous open end lines and hose connections. And because of very frequent operation, the valves formerly used in these lines required more than usual servicing to keep up with leakage, dripping hose lines, and hazardous, messy floors.

Crane No. 1610 Diaphragm valves were selected to replace the troublesome conventional valves. Immediately these packless valves stopped the annoyance and expense of stuffing box and seat leakage. Their pliable disc insert ring made a tight seat on open end lines with minimum effort on handwheels.

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(*Continued from page 48 P&R*)

WANTED—a copy of the August 1948 issue of the British publication, *Journal of the Institution of Water Engineers* (Vol. 2, No. 5) to complete the file at AWWA headquarters. Can anyone make us an offer? Please address the managing editor, Journal American Water Works Assn., 521—5th Ave., New York 17, N.Y., and mention asking price.

A new soft-water servicing firm, the John H. Nickerson Co., has been organized with headquarters at 410 Fort Wayne National Bank Bldg., Fort Wayne, Ind., and plans to operate on a nationwide scale. Service will be supplied by local dealers on a rental basis to domestic customers, and the dealers in turn will rent the softening units from the parent organization.

Paul A. Coffman, chief engineer of Omega Machine Co., has been elected vice-president of the firm. In addition to his new duties, he will continue as chief engineer and as a member of the board of directors.

H. Arthur Price, specification section head for the water system of the Los Angeles Dept. of Water & Power, has been awarded a 25-year service certificate from his department. He began as a topographical draftsman in 1928.

Ivan V. Fosheim has resigned as superintendent of the Pontiac, Mich., Dept. of Water Supply to become works manager for the Challenge Stamping & Porcelain Co. of Grand Haven, Mich.

(*Continued on page 78 P&R*)

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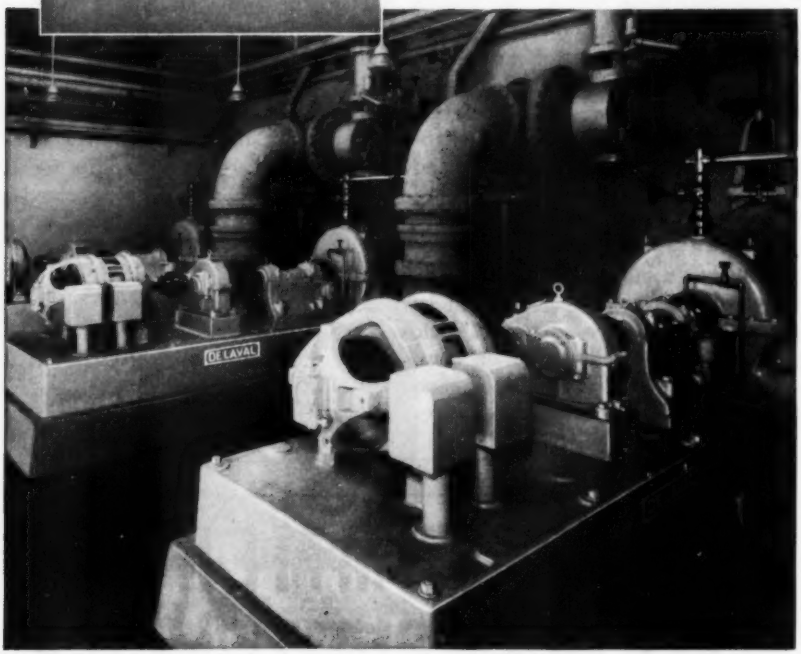

Three De Laval sewage pumps are on the job in the City of Baltimore's new Brooklyn Sewage Pumping Station built for today's need and planned for future expansion.

Two of these high efficiency motor-driven horizontal pumps have a capacity of 3,000 gpm and the third a capacity of 7,000 gpm. Later, as flow increases, the two 3,000 gpm units can be replaced by a 7,000 gpm pump.

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Baltimore is another of a long list of cities being served by De Laval pumps. A complete centrifugal pump line is built on 50 years experience at De Laval — pioneer in the municipal pumping field.

DE LAVAL *Sewage Pumps*

DE LAVAL STEAM TURBINE COMPANY
822 Nottingham Way, Trenton 2, New Jersey

DL 171A

(Continued from page 76 P&R)

"The voice with a smile" did some fast talking last June 11 when a broken check valve in the Indianapolis Water Co. Fall Creek Pumping Station disrupted water service in half the city for more than nine hours. No sooner had the pressure dropped and the company employees been put on emergency duty than the phone began to ring its head off. Then it was that the chief operator at the affected city switchboard took stock of the situation and instructed the girls at the switchboard to intercept any calls to the water company with this word: "The water company has a bursted main and they are aware of the trouble. It will be repaired as soon as possible." A little light on grammar, but heavy on common sense and cooperativeness, and most effective in relieving the water company personnel in time of stress. All of which has water utility personnel so grateful they're calling their bell and spigot pipe, Bell and spigot.

Remembering how many of our neighbors jam our phone with calls every time we incinerate the contents of our vacuum cleaner, we asked the Bell boys if this type of aid to the overcalled could normally be expected. "Normally, no," was the answer, "only when an emergency affecting the community as a whole is involved will telephone company personnel come to the rescue." Even that, though, is good to know.

Samuel P. Felix has been appointed general manager of De Laval Turbine Pacific Co., a subsidiary of De Laval Steam Turbine Co.

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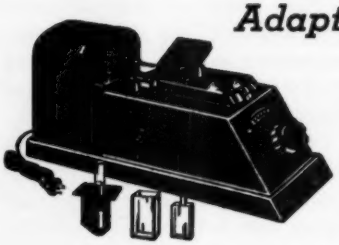

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Flocculation equipment utilizing paddle design for slow mixing is the subject of Technical Supplement PF of American Well Works, Aurora, Ill. Description, drawings, and explanation occupy ten loose-leaf pages.

Soil testing apparatus offered by Soiltest, Inc., is the subject of a 72-p. catalog, available from the firm at 4522 W. North Ave., Chicago 39, Ill. In addition to listing equipment for consolidation, compaction, and other tests of the mechanics of the soil, a section on equipment for chemical and agricultural soil tests is included.

Rubber hose maintenance is the subject of a bulletin distributed by Hewitt-Robins Inc., 240 Kensington Ave., Buffalo, N.Y. Entitled "Tips on Hose Care," the 4-p. folder discusses hose intended for various industrial applications.

Orifice meters in the Rockwell "201" line are described in a 28-p. bulletin distributed on request by Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.

Sparling Meter Co. products are listed in Bul. 313, a new catalog of water control equipment. Copies may be had from the firm, Box 3277 Terminal Annex, Los Angeles 54, Calif.

High-test hypochlorite, its application, and a table of solution strengths and dosages are discussed in a 24-p., pocket-size booklet on Pittchlor issued by Columbia-Southern Chemical Corp., 420 Fort Duquesne Blvd., Pittsburgh 22, Pa.

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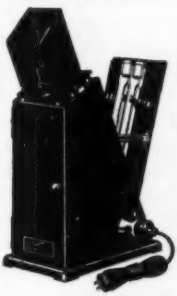

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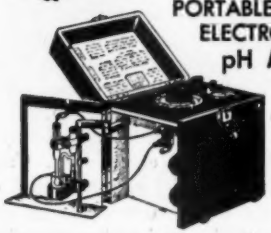

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Section Meetings

Kansas Section: The eighth annual joint meeting of the Kansas Section with the Kansas Sewage & Industrial Waste Assn. was held April 22–24 at the Broadview Hotel in Wichita. The total registered for the meeting was 170 members and guests.

The program for this joint meeting had been jointly prepared by Dar Soder, vice-chairman of the Kansas Section, and Dwight F. Metzler, secretary-treasurer of KSIWA.

H. H. Kansteiner, director of the Kansas Section, presided over the opening session of the water works group. An excellent movie on the manufacture of cast-iron pipe was shown by the courtesy of the Cast Iron Pipe Research Assn. Harold Null, of the Null Investment Co., Wichita, explained methods by which water works projects could be financed.

Later in the afternoon the two groups combined into a general session to discuss the effects of synthetic detergent pollution on the operation of water softening plants and sewage treatment plants. Russell Culp of the State Board of Health and J. J. Higgins, water superintendent of Osawatomie, presented a discussion on how these detergents had created a serious operating problem at the water softening plant at Osawatomie this past winter.

The second general session opened Thursday morning with Robert J. Mounsey, chairman of the Kansas Section, presiding. The welcoming address was given by R. B. Price, Chief of Police, Wichita. Greetings from the national Association were extended by Morrison B. Cunningham, AWWA president-elect.

The first technical paper on the morning program was given by Glenn E. Hands, engineer for Burns & McDonnell, who described the McIlroy analyzer and discussed its use in analyzing existing and future pipeline networks.

A comparison of the chemical results obtained by operating a water softening plant with conventional type settling basins and solids-contact units was presented by Quintin F. Graves of the Oklahoma A&M civil engineering department.

"Research in the Possible Transmission of Histoplasmosis by Water" was the subject for the discussion by Dwight F. Metzler, chief engineer, State Board of Health. He described the research conducted by the board in cooperation with allied research groups at the Univ. of Kansas in identifying, isolating, and culturing the causative fungus.

Fred D. Diehl of McPherson and Russell Culp of Lawrence presided at the afternoon session. G. J. Manahan, general sales manager of A. P. Smith Mfg. Co., discussed the needs and the proper procedures for inserting gate valves in water lines under pressure. Movies were shown illustrating the procedure used for installing two valves under pressure.

Two lively round-table discussions completed the program for the afternoon. The first, entitled "Cutting the Costs of Sewage Treatment," was developed by Kenneth Pack, Cedarvale; Bill Parr, Topeka; and James Snell, Kingman; telling how each had reduced maintenance and operating costs in their particular plants. O. O. Ediger, Ediger Eng. Co., and Ray Lawrence, Black & Veatch Eng. Co., then showed methods by which capital expenditures for new plants could be reduced.

The second round-table, entitled "Long Range Planning for Water Utilities," was

(*Continued on page 84 P&R*)

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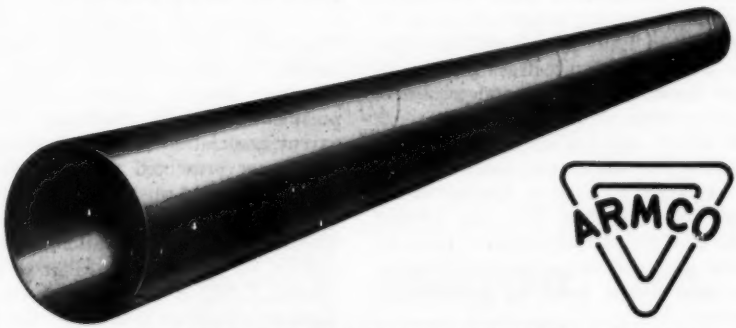


ARMCO

ARMCO WELDED STEEL PIPE

Meets A. W. W. A. Specifications

Section Meetings

(Continued from page 82 P&R)

devoted to supply, treatment, and distribution problems. Robert H. Hess, Wichita, told of plans for future expansion of the existing well fields and also the long-range plan for supplementing the well supply with a surface supply 70 miles distant. L. S. McArthur, Mission, discussed the long-range plan for his company to build a river supply treatment plant. Murray Wilson, Wilson & Co., Salina, discussed the plans of Salina for a water-softening system. Harold Volkman, Clay Center, stressed the importance of large size trunk lines in forecasting distribution requirements.

The annual banquet was held Thursday evening with Robert J. Mounsey, Lawrence, presiding. The principal speaker was Kingsley W. Given, who gave a very interesting and informative talk on "New Frontiers."

A past-chairman's certificate was presented to Robert H. Hess at the Banquet. Secretary Harry W. Badley announced that the George Warren Fuller Award is to be presented to Major C. Hagar, Sterling, for outstanding achievement.

A. W. Rumsey, Kansas City, presided at the Friday morning general session. Gordon Mau, chief of the Water Pollution Central Section of the State Board of Health, presented a very interesting discussion of sewage treatment plants in Germany and England. Excellent color slides were shown illustrating the important features of design and treatment as used in these plants.

The theory and application of cathodic protection for submerged steel surfaces were explained by Fred A. Daniels of the Electro Rust-Proofing Co. He pointed out the need for careful design of cathodic systems and the importance of regular inspection of the units by experienced operators.

Morrison B. Cunningham discussed some of the many problems that may be encountered in a distribution system, and how the percentage of unaccounted-for water can be reduced by inspection of distribution facilities.

A round-table discussion on the chemicals and equipment used for fluoridating Kansas water supplies concluded the morning program. Opening the discussion was a report on the use of Flural as the fluoridating chemical at Ottawa by O. L. E. Haff. Paul J. Bush, Iola, showed how fluosilicic acid was used at his plant and remarked on the ease by which this chemical could be used at smaller plants. Anthony Younger, Hays, described the procedure used at his plant employing gravimetric feeders and sodium silicofluoride. A lengthy discussion on the use of these various type chemicals and feeders followed these three reports.

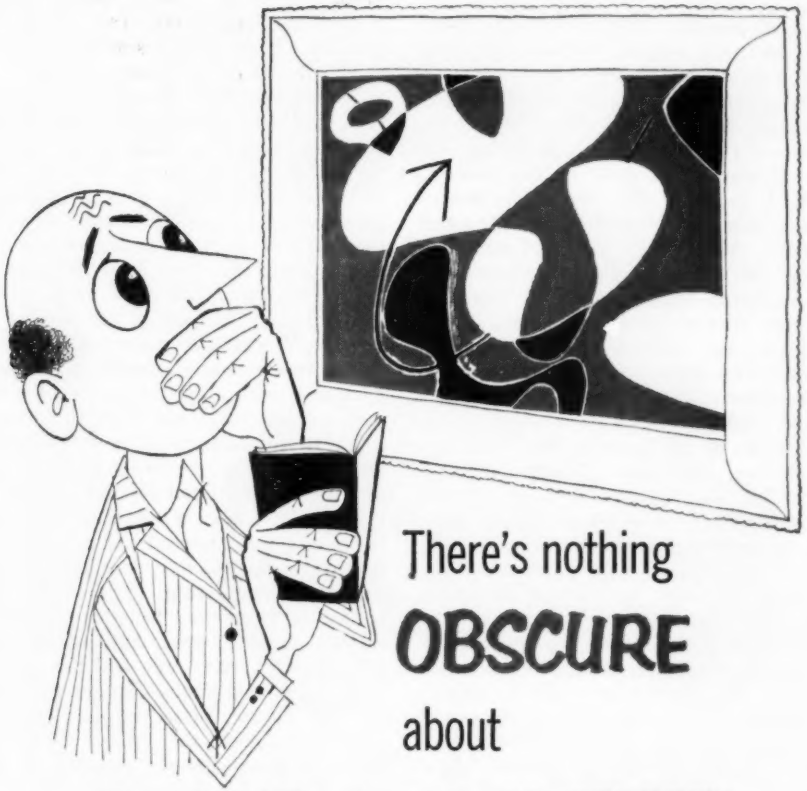
After a business luncheon, reports from the various committees of each group were given Friday afternoon. The business meeting closed after the introduction and remarks of the newly elected officers.

H. W. BADLEY
Secretary-Treasurer

Pennsylvania Section: The Pennsylvania Section held the fifth annual meeting on June 17–19, 1953, at the Community Inn in Hershey. The total registration was 204, including members and guests.

An interesting and diversified program was presented at this meeting, which began Wednesday afternoon, with Chairman L. S. Duckworth presiding. A film on fluoridation was shown—"A Drop in the Bucket," prepared by the Public Health Service. Dale L. Maffitt, AWWA vice-president, brought greetings from the parent association to the members. The first paper presented at this session was by Kenneth C. Armstrong, superintendent of the Municipal Filter Plant at Chester, on "Some Early Observations on the Operation of the New Filter Plant at Chester." "The Influence of Operating Data on Original Works on the Design of Extensions to Major Filter Plants" was discussed by Marsden C. Smith, chief water engineer, Dept. of Public Utilities, Richmond. Lewis J. Klockner, superintendent, Municipal Water Works, Trenton, N.J., discussed the Trenton plant.

(Continued on page 86 P&R)



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Section Meetings

(Continued from page 84 P&R)

J. D. Johnson, past-chairman of the section, presided over the Thursday morning technical session. A movie, "Every Drop to Drink," prepared by the London Metropolitan Water Board, was presented. A panel discussion on "How Should the Costs of Highway Relocation Be Met and by Whom?" was held at this session, with I. S. Sahli, chairman of the Beaver Falls Municipal Authority, as the panel leader. Members of the panel were Ellwood H. Aldrich, chief engineer, and J. G. Carns, engineer, both of American Water Works Service Co., Inc., Philadelphia; and Charles F. LeeDecker, assistant executive secretary, Inst. of Local Government, Pennsylvania State College, State College.

Movies again preceded the papers on Thursday afternoon. "Water for Millions," a film on the water supply for Los Angeles, was shown at the beginning of the session, which was presided over by L. D. Matter, vice-chairman of the section. A paper on "Recent Investigations on Ground Water Conditions in the Pittsburgh Area" was presented by R. M. Leggette, consulting ground water geologist of New York; and John R. Baylis, engineer of water purification, Bureau of Engineering, Dept. of Public Works, Chicago, spoke on "Corrosion of Water Mains." Completing the Thursday afternoon session was a paper on "Forestry and Watersheds" by M. K. Goddard, professor of forestry, Pennsylvania State College.

The final technical sessions on Friday morning opened with a paper on "Research and Experimentation in the Water Works Field" by Martin E. Flentje, research engineer, American Water Works Service Co., and R. Rupert Kountz, professor of sanitary engineering, Pennsylvania State College. William B. Hess, senior test engineer, Safe Harbor Water and Power Corp., Lancaster, and R. C. Swengel, consultant, York, discussed "The Development of an Ultrasonic Flow Meter." The technical sessions ended with a paper on "Cost Indexes for Water Works Property" by Henry H. Fick, of Weber, Fick & Wilson, Public Utility Consultants, Harrisburg (see this issue, p. 779). This Friday session was presided over by R. B. Adams, trustee.

The Oyster Bar at Community Inn was the scene for the informal gathering Tuesday for the early arrivals. On Wednesday, the ladies attending the meeting were taken on a tour of Hershey, and golfing facilities were available for anyone interested in this sport. The annual convention get-together was held Wednesday evening at the Park Golf Club, given through the courtesy of the Water & Sewage Works Manufacturers Assn.

The entertainment schedule was heavy Thursday, with a golf tournament for the men, a bridge luncheon at Hershey Country Club for the forty ladies and a luncheon for the men, honoring the new life members of the Pennsylvania Section at Community Club. At this luncheon the honored guests present were given an award in recognition of their faithful and continued membership. The social hour preceding the annual banquet, sponsored by the manufacturers association, was held at the Oyster Bar and the annual dinner was held at the Community Club. At this dinner Vice-President Dale L. Maffitt spoke to the group. John D. Johnson, general superintendent of the Erie Bureau of Water was selected to receive the George Warren Fuller Award. Golf prizes and door prizes were also given out at this dinner. The members and guests were entertained by the Shepperd Twins and the Grantley Flame Throwers Quartette.

During the business meeting on Wednesday, committee reports were given and L. D. Matter presented a report on the activities of the Civil Defense Committee. On Friday, at the business session, the new officers for the coming year were elected. These include L. D. Matter, chairman; J. L. Matthews, vice-chairman; L. S. Morgan, secretary-treasurer and P. W. Miller, trustee for a period of three years.

L. S. MORGAN
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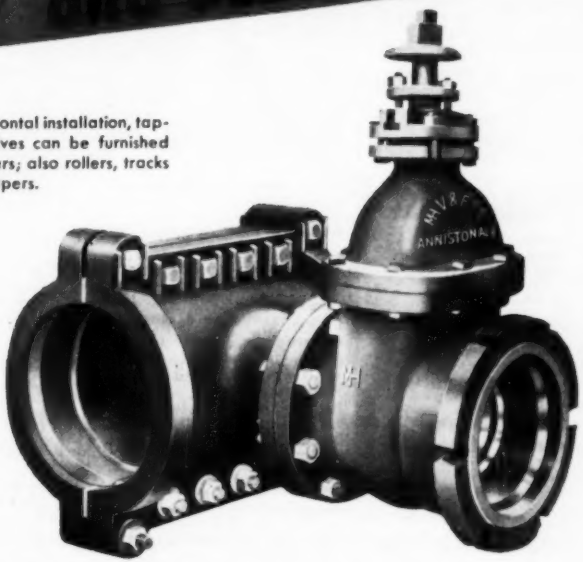

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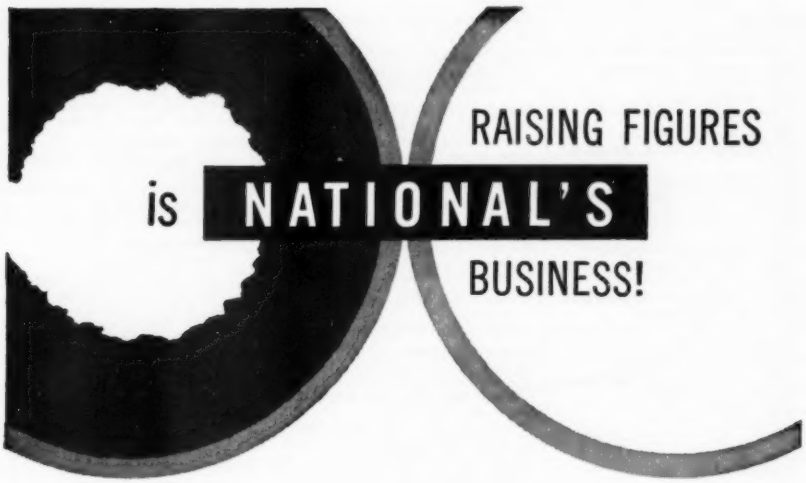

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Jos. G. Pollard Co., Inc.

Lime Slakers and Feeders:
Dorr Co.
Infilco Inc.
Omega Machine Co. (Div., Builders Iron Fdry.)
Permutit Co.

Magnetic Dipping Needles:
W. S. Darley & Co.

Meter Boxes:
Ford Meter Box Co.
Pittsburgh Equitable Meter Div.

Meter Couplings and Yokes:
Badger Meter Mfg. Co.
Dresser Mfg. Div.
Ford Meter Box Co.
Hays Mfg. Co.
Hersey Mfg. Co.
James Jones Co.
Mueller Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Smith-Blair, Inc.
Worthington-Gamon Meter Co.

Meter Reading and Record Books:
Badger Meter Mfg. Co.

Meter Testers:
Badger Meter Mfg. Co.
Ford Meter Box Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.

Meters, Domestic:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Well Machinery & Supply Co.
Worthington-Gamon Meter Co.

Meters, Filtration Plant, Pumping Station, Transmission Line:
Builders-Providence, Inc.
Infilco Inc.
Simplex Valve & Meter Co.
Sparling Meter Co., Inc.

Meters, Industrial, Commercial:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Builders-Providence, Inc.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Simplex Valve & Meter Co.
Sparling Meter Co., Inc.
Well Machinery & Supply Co.
Worthington-Gamon Meter Co.

Mixing Equipment:
Chain Belt Co.
Infilco Inc.
Walker Process Equipment, Inc.

Ozonation Equipment:
Welsbach Corp., Ozone Processes Div.

Pipe, Asbestos-Cement:
Johns-Manville Corp.
Keasbey & Mattison Co.

Pipe, Brass:
American Brass Co.

Pipe, Cast Iron (and Fittings):
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Crane Co.
McWane Cast Iron Pipe Co.
Pacific States Cast Iron Pipe Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Cement Lined:
Cast Iron Pipe Research Assn.
James B. Clow & Sons
McWane Cast Iron Pipe Co.
Pacific States Cast Iron Pipe Co.
Southern Pipe & Casing Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe Coatings and Linings:
The Barrett Div.
Cast Iron Pipe Research Assn.
Centriline Corp.
Koppers Co., Inc.
Pipelife, Inc.
Reilly Tar & Chemical Corp.
Southern Pipe & Casing Co.

Pipe, Concrete:
American Concrete Pressure Pipe Assn.
American Pipe & Construction Co.
Lock Joint Pipe Co.
Universal Concrete Pipe Co.

Pipe, Copper:
American Brass Co.

Pipe Cutting Machines:
James B. Clow & Sons
Ellis & Ford Mfg. Co.
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Pipe Jointing Materials; see Jointing Materials

Pipe Locators:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pipe, Plastic:
Carlon Products Corp.

Pipe, Steel:
Armco Drainage & Metal Products, Inc.
Bethlehem Steel Co.
Southern Pipe & Casing Co.

Plugs, Removable:
James B. Clow & Sons
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Potentiometers:
Hellige, Inc.

Pressure Regulators:
Allis-Chalmers Mfg. Co.
Mueller Co.
Ross Valve Mfg. Co.

Pumps, Boiler Feed:
DeLaval Steam Turbine Co.

Pumps, Centrifugal:
Allis-Chalmers Mfg. Co.
American Well Works
DeLaval Steam Turbine Co.
Economy Pumps, Inc.
Morse Bros. Mchy. Co.

Pumps, Chemical Feed:
Infilco Inc.
Proportioneers, Inc.
Wallace & Tiernan Co., Inc.

Pumps, Deep Well:
American Well Works
Layne & Bowler, Inc.

Pumps, Diaphragm:
Dorr Co.
Morse Bros. Mchy. Co.

Pumps, Hydrant:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pumps, Hydraulic Booster:
Ross Valve Mfg. Co.

Pumps, Sewage:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
Economy Pumps, Inc.

Pumps, Sump:
DeLaval Steam Turbine Co.
Economy Pumps, Inc.

Pumps, Turbine:
DeLaval Steam Turbine Co.
Layne & Bowler, Inc.

Recorders, Gas Density, CO_2, NH_3, SO_2, etc.:
Permutit Co.
Wallace & Tiernan Co., Inc.

BOARD OF PUBLIC AFFAIRS
MILLERSBURG, OHIO

June 24, 1953

Simplex Valve & Meter Co.
Philadelphia 42, Pa.

Gentlemen:

We have acquired a Simplex Venturi main line meter from the City of Wooster, Ohio. This meter was sold to City of Wooster on May 4, 1912.

We plan to install this meter on our main line at Millersburg, Ohio Water Plant. Will you please send me descriptive information and parts list for this meter.

Markings on identification plate are as follows:
8" Tube 4" Throat #8-43-548-G.D. MSD 38.187
May 4, 1912 Markings on Cover Plate #546

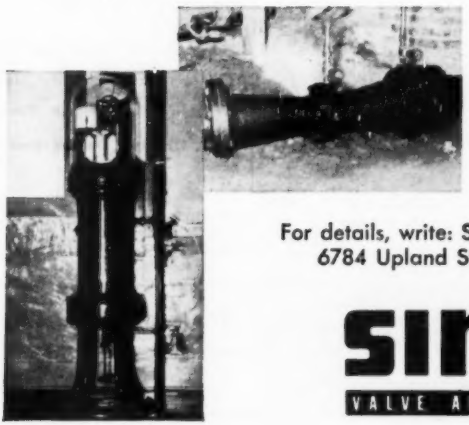
Address reply to: C. R. Deitrich, Supt. of W.W.

Respectfully,

C. R. Deitrich

C. R. Deitrich

Another proof that Simplex is reliable in the long run!



Simplex Meter and Venturi Tube recently installed after service of over 40 years!

For details, write: Simplex Valve & Meter Company, 6784 Upland Street, Philadelphia 42, Penna.

SIMPLEX®
VALVE AND METER COMPANY

Recording Instruments:
Infilco Inc.
Sparling Meter Co., Inc.
Wallace & Tiernan Co., Inc.

Reservoirs, Steel:
Chicago Bridge & Iron Co.
Pittsburgh-Des Moines Steel Co.

Sand Expansion Gages; see Gages

Sleeves; see Clamps

Sleeves and Valves, Tapping:
James B. Clow & Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

Sludge Blanket Equipment:
Permutit Co.

Soda Ash:
Solvay Process Div.

Sodium Hexametaphosphate:
Blockson Chemical Co.
Calgon, Inc.

Softeners:
Belco Industrial Equipment Div.
Dorr Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Softening Chemicals and Compounds:
Calgon, Inc.
Infilco Inc.
Permutit Co.
Tennessee Corp.

Standpipes, Steel:
Chicago Bridge & Iron Co.
Pittsburgh-Des Moines Steel Co.

Steel Plate Construction:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Pittsburgh-Des Moines Steel Co.

Stops, Curb and Corporation:
Hays Mfg. Co.
James Jones Co.
Mueller Co.
A. P. Smith Mfg. Co.

Storage Tanks; see Tanks

Strainers, Suction:
James B. Clow & Sons
M. Greenberg's Sons
Johnson, Edward E., Inc.
R. D. Wood Co.

Surface Wash Equipment:
Permutit Co.

Swimming Pool Sterilization:
Omega Machine Co. (Div., Builders Iron Fdry.)
Proportioneers, Inc.
Wallace & Tiernan Co., Inc.
Welsbach Corp., Ozone Processes Div.

Tanks, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Pittsburgh-Des Moines Steel Co.

Tapping Machines:
Hays Mfg. Co.
Mueller Co.
A. P. Smith Mfg. Co.

Taste and Odor Removal:
Industrial Chemical Sales Div.
Infilco Inc.
Permutit Co.
Proportioneers, Inc.
Wallace & Tiernan Co., Inc.
Welsbach Corp., Ozone Processes Div.

Turbidimetric Apparatus (For Turbidity and Sulfate Determinations):
Hellige, Inc.
Wallace & Tiernan Co., Inc.

Turbines, Steam:
DeLaval Steam Turbine Co.

Turbines, Water:
DeLaval Steam Turbine Co.

Valve Boxes:
James B. Clow & Sons
Ford Meter Box Co.
M & H Valve & Fittings Co.
Mueller Co.
Pacific States Cast Iron Pipe Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valve-Inserting Machines:
A. P. Smith Mfg. Co.

Valves, Altitude:
Davis Mfg. Co.
Ross Valve Mfg. Co., Inc.

Valves, Butterfly, Check, Flap, Foot, Hose, Mud and Plug:
James B. Clow & Sons
Crane Co.
M. Greenberg's Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
R. D. Wood Co.

Valves, Detector Check:
Hersey Mfg. Co.

Valves, Electrically Operated:
Belco Industrial Equipment Div.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Davis Mfg. Co.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Philadelphia Gear Works, Inc.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

Valves, Float:
James B. Clow & Sons
Davis Mfg. Co.
Ross Valve Mfg. Co., Inc.

Valves, Gate:
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Dresser Mfg. Div.
James Jones Co.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Pacific States Cast Iron Pipe Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Hydraulically Operated:
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Davis Mfg. Co.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Philadelphia Gear Works, Inc.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Large Diameter:
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Davis Mfg. Co.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Regulating:
Crane Co.
Davis Mfg. Co.
Mueller Co.
Ross Valve Mfg. Co.

Valves, Swing Check:
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
M. Greenberg's Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Waterproofing
Inertol Co., Inc.

Water Softening Plants; see Softeners

Water Supply Contractors:
Layne & Bowler, Inc.

Water Testing Apparatus:
Hellige, Inc.
Wallace & Tiernan Co., Inc.

Water Treatment Plants:
Allis-Chalmers Mfg. Co.
American Well Works
Belco Industrial Equipment Div.
Chain Belt Co.
Chicago Bridge & Iron Co.
Dorr Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Pittsburgh-Des Moines Steel Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.
Wallace & Tiernan Co., Inc.
Welsbach Corp., Ozone Processes Div.

Well Drilling Contractors:
Layne & Bowler, Inc.

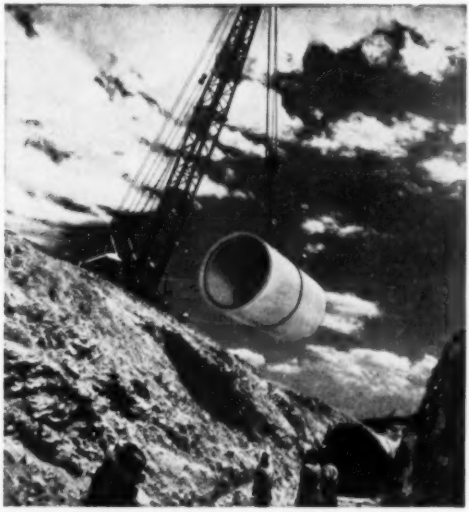
Well Screens
Johnson, Edward E., Inc.

Wrenches, Ratchet:
Dresser Mfg. Div.

Zeolite; see Ion Exchange Materials

A complete Buyers' Guide to all water works products and services offered by A.W.W.A. Associate Members appears in the 1950 Membership Directory.

Denver Prefers Concrete Pressure Pipe



Thirty-two years ago the city of Denver installed its first concrete pressure pipe. From time to time, as the demands for water increased, Denver has added to its water transmission system . . . and the pipe selected most has been concrete pressure pipe.

Denver engineers give these reasons for this preference: (1) the permanent high carrying capacity of concrete pipe, (2) the immunity to blow-out or rupture, (3) proof against tuberculation, corrosion, and electrolytic damage, (4) extremely long life and maintenance economy.

The performance in Denver and in other cities, both large and small, throughout the country proves the distinct advantages offered by concrete pressure pipe. Let us show you how these same advantages can be used for the water system in your community.

Water for Generations to come

Concrete PRESSURE Pipe

AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION
228 North LaSalle Street
Chicago 1, Illinois

The Symbol for Service, Quality and Performance in Water Meters

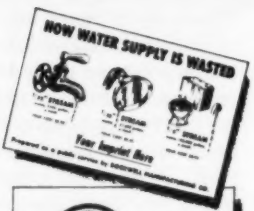
Rockwell Meter Service Aids

YOURS FOR THE ASKING In the Interests of a Better Public Understanding of the Great and Growing Water Works Industry.

MADE TO MEASURE *A Film Illustrating Your Silent, Faithful Friend—the Water Meter.* A 16 mm film utilizing sound and color—running time, 30 minutes. This movie is now available for showings at association meetings, civic groups and educational institutions. When requesting a print, please anticipate your needs by at least a month and if possible give an alternate date.

Water Waste Post Cards

Illustrate how water is wasted by small leaks. Cuts available for imprinting post cards or for use in newspapers.

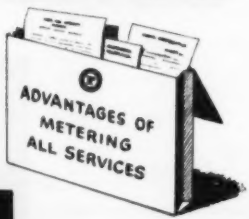


"Read Your Own Meter" Post Cards

Cuts of dial faces of registers are available for printing these cards. Specify type of register cut desired, i.e. whether straight or circular reading, recording in gallons or cubic feet.

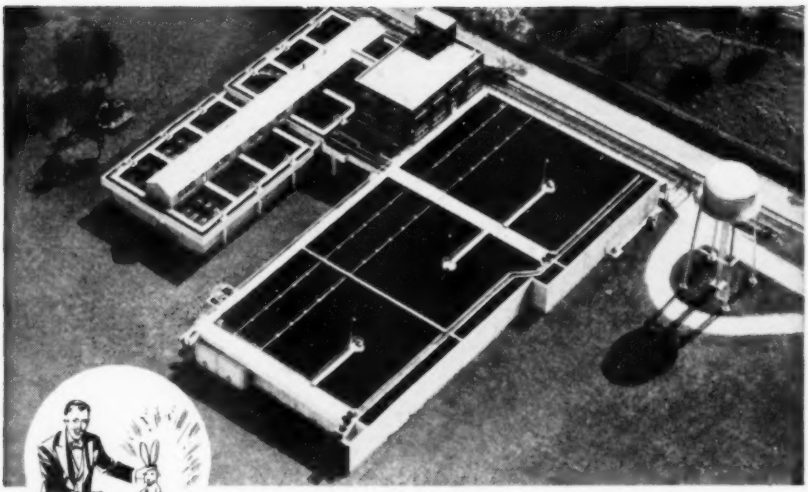
Portfolio of Facts on Advantages of 100% Metering

Contains case histories of "before and after" metering experiences, reprints of prize winning essays on 100% metering, publicity stories for release to local newspapers.



ROCKWELL MANUFACTURING COMPANY

PITTSBURGH 8, PA. ATLANTA BOSTON CHICAGO HOUSTON KANSAS CITY
LOS ANGELES NEW YORK PITTSBURGH SAN FRANCISCO SEATTLE TULSA



There's No "Magic Formula"

Every water treatment problem is different

No two water treatment problems are exactly alike. To get the best — and most economical — answer to your specific problem requires careful analysis of raw water composition, rate of flow and the results you require.

There *is* no magic formula . . . no single equipment unit that will give ideal results under all conditions. That's why it will pay you to check both conventional and high-rate units on every water treatment problem.

For a brief picture of the complete Dorr equipment line ask for Bulletin #9141. The Dorr Company, Stamford, Conn.

Repeat order in 1950 "proves out" a "conventional" installation made in 1948.

Quick facts about the Dorrco installation at the
Hollingsworth & Whitney Co., Chickasaw Mills, Mobile, Alabama

1948 . . . First order installed with a design capacity of 10 MGD: 2 Dorrco Flash Mixers, 1 Dorrco Flocculator, 1 Dorrco Squarex Clarifier, 85′ square.

Operating Results . . . Raw water: Color — 65-70 ppm, Raw water: Turbidity — 3.5-3.9 ppm, Finished water: Color — 3 ppm (Dosage in ppm: Alum 20, Soda Ash 15, Chlorine 3 to 5)

1950 . . . Second order installed with design capacity of 16 MGD (Total design capacity: 26 MGD): 1 Dorrco Flash Mixer, 2 Dorrco Flocculators, 2 Dorrco Squarex Clarifiers, 75′ square.

Flocculator and Squarex are trademarks of THE DORR COMPANY — Reg. U. S. Pat. Off.

Every day, nearly 8 billion gallons of water are treated by DORR equipment.

Better tools TODAY to meet tomorrow's demand

DORRCO

DORR

WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT

THE DORR COMPANY • ENGINEERS • STAMFORD, CONN.

Offices, Associated Companies or Representatives in principal cities of the world.

LEADITE

Trade Mark Registered U. S. Pat. Office

Jointed for . . . Permanence with LEADITE

Generally speaking, most Water Mains are buried beneath the Earth's surface, to be forgotten,—they are to a large extent, laid for permanency. Not only must the pipe itself be dependable and long lived,—but the joints also must be tight, flexible, and long lived,—else leaky joints are apt to cause the great expense of digging up well-paved streets, beautiful parks and estates, etc.

Thus the "jointing material" used for bell and spigot Water Mains MUST BE GOOD,—MUST BE DEPENDABLE,—and that is just why so many Engineers, Water Works Men and Contractors aim to PLAY ABSOLUTELY SAFE, by specifying and using LEADITE.

Time has proven that LEADITE not only makes a tight durable joint,—but that it improves with age.

The pioneer self-caulking material for c. i. pipe.
Tested and used for over 40 years.
Saves at least 75%

THE LEADITE COMPANY
Girard Trust Co. Bldg. Philadelphia, Pa.

No Caulking